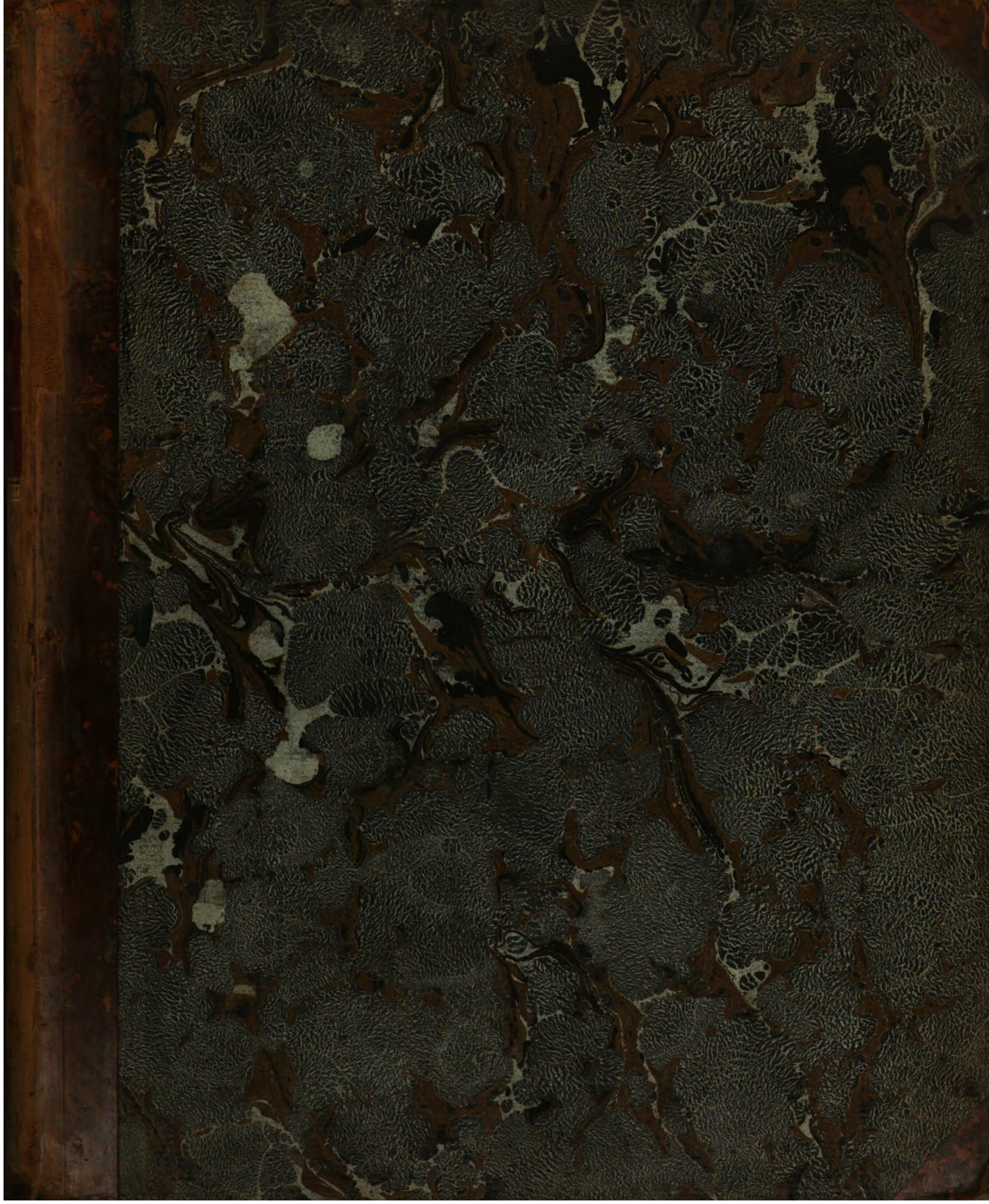
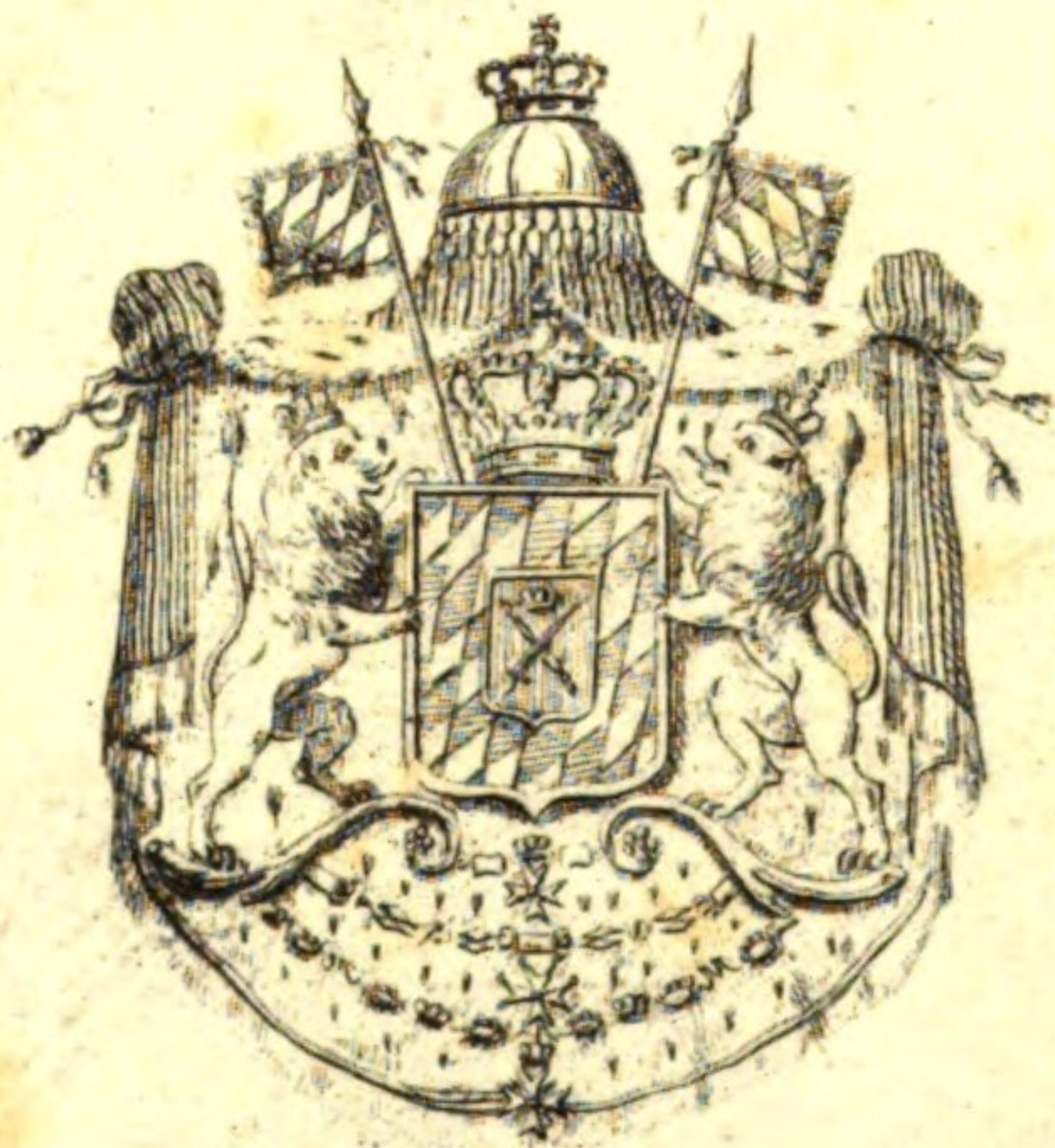




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OF THE LATE

R JOHN S MEATON, F.R.S.

VOL. II.

REPORTS

OF THE LATE

JOHN SMEE, F.R.S.

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R E P O R T S

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JOHN SMEATON, F.R.S.

MADE ON

VARIOUS OCCASIONS,

IN THE COURSE OF HIS EMPLOYMENT

AS

A CIVIL ENGINEER.

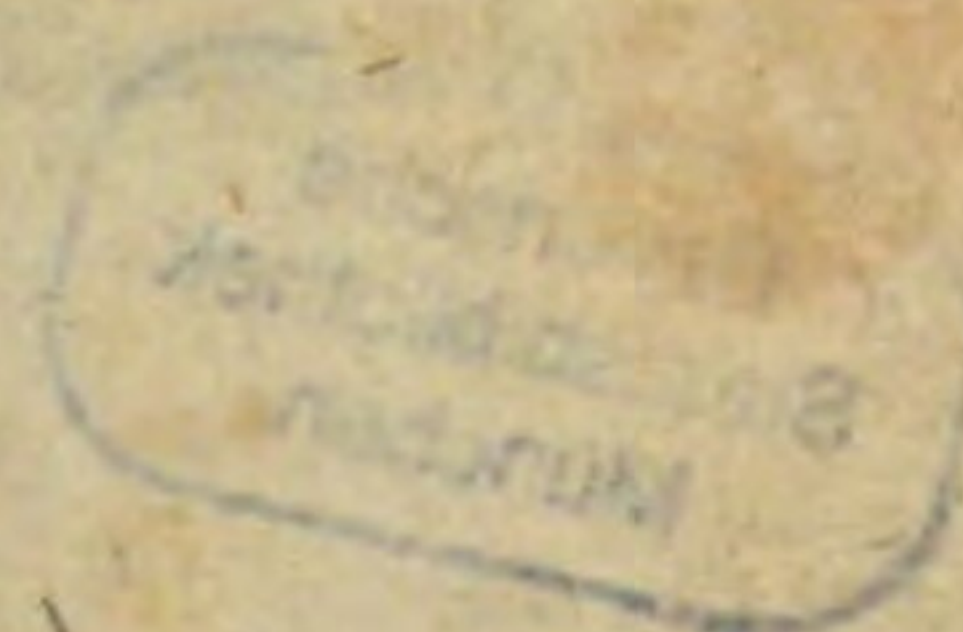
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VOL. II.

LONDON:

PRINTED FOR LONGMAN, HURST, REES, ORME, AND BROWN,
PATERNOSTER-ROW.

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SECTION OF THE WATER WAY AT LONDON BRIDGE, AS IT WAS BEFORE & AFTER THE OPENING OF THE GREAT ARCH.

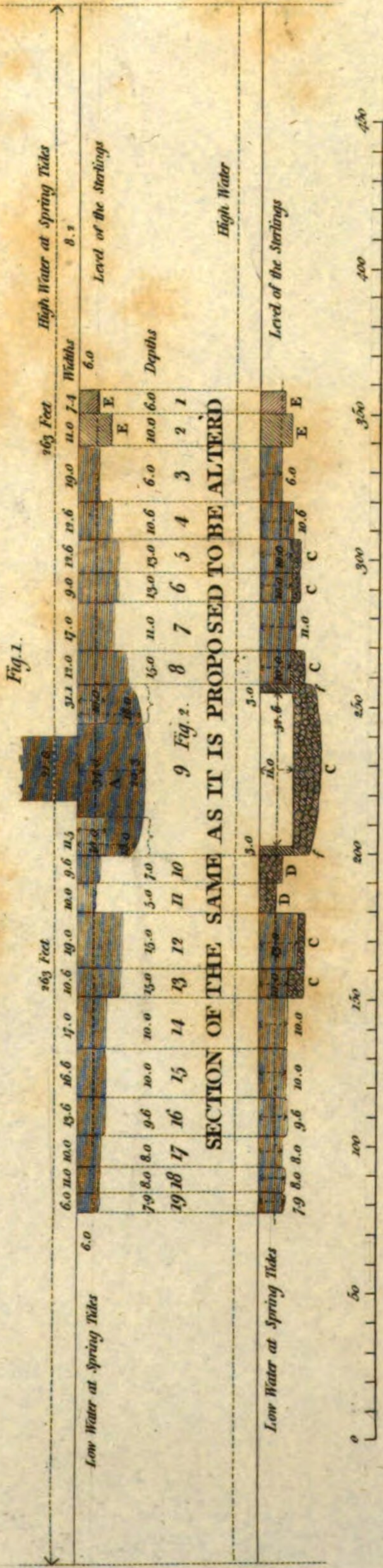
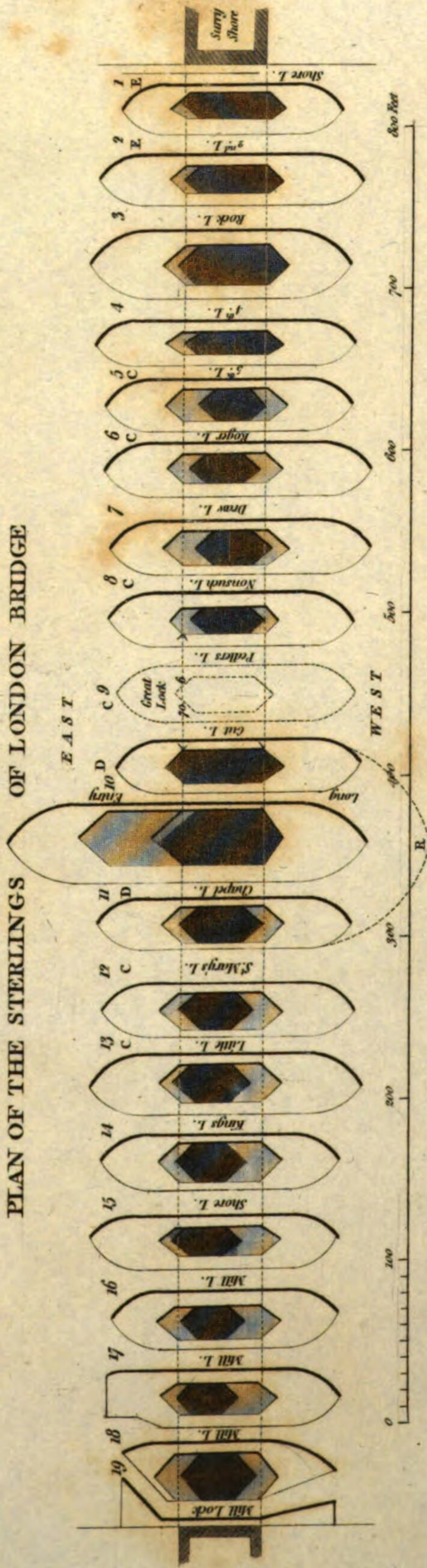
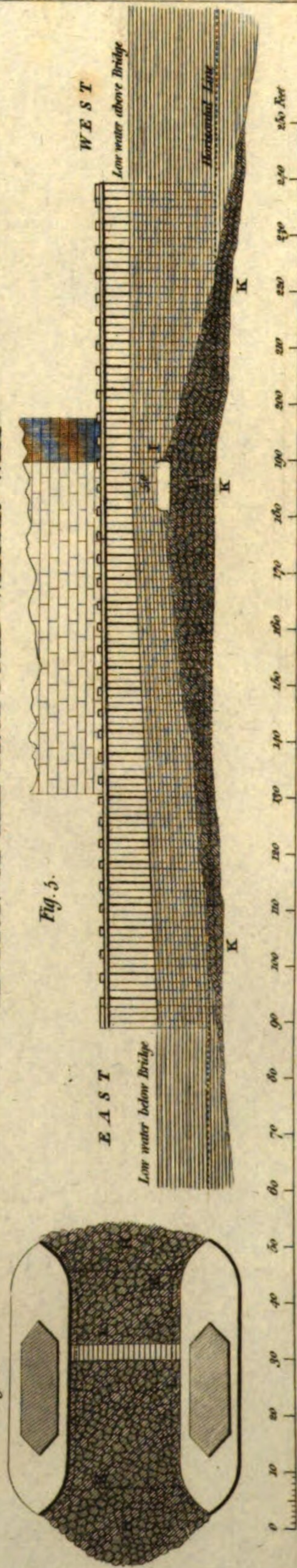


Fig. 3.
PLAN OF THE STERLINGS
OF LONDON BRIDGE



PLAN
Fig. 4.

SECTION OF THE PROPOSED WATER WAY



REPORTS, &c.

LONDON BRIDGE.

The REPORT of JOHN SMEATON, upon the QUESTIONS proposed to him by the Committee for improving, widening, and enlarging London Bridge.

Question 1st. **I**N what degree, at a monthly average, is the natural power of the water, and effect thereof, upon the wheels of London Bridge water-works diminished, by removal of the pier, and opening of the great arch?

Answer.—By calculation it appears, that the natural power of the water, as the circumstances of the great arch were in the beginning of February, 1763, was diminished at the monthly average as 2000 to 1277; and that the effect thereof upon the wheels, as appears by the company's register, for above six years past, was diminished in proportion of 2000 to 1300. The process of which investigation is hereto annexed.

Question 2d.—What are the methods, whereby the effect of these works may be restored to the same quantity, with respect to raising water, as subsisted before the opening of the great arch?

Answer.—The methods that can be put in practice, for restoring the effect of the works, are reducible to two, viz: by improving and enlarging the present works, or
Vol. II. B by

by penning up the same head of water as before the alteration. With respect to the present wheels, though they are all capable of improvement, yet they cannot all be improved in the same degree in which they are now deficient, nor can they be so much improved taken collectively; it will, therefore, be necessary, not only to improve some of the present wheels, but to add a new one; but as the old wheels cannot be much improved without rebuilding, and *one* new one cannot be depended upon to make good the deficiency, without rebuilding some of the old ones; as the power, while acting, must be increased, in order to do the same business in a less time, and as the present mains are but barely adequate to the present wheels, (which appears from their refusing a part of the water thrown up by the engines during the action of the strong spring tide, as has happened during my examination of the works), it follows, that the addition of wheels will require an addition of mains, which, upon the whole, will create a great expense, and of a very complex nature. On the other hand, the very same expedient that will be necessary for securing the great arch, will also contribute considerably towards the relief of the water-works; I, therefore, think it more eligible for the committee not to engage in building or improving the water-works, but to proceed to such method as will restore the head of water; which may be done, as I conceive, at a less expense, and not only without prejudice to the navigation, but in some respects be an aid thereto, and that is by raising the bed of the great lock, and some others, that are unnecessarily deep, and by stopping the water-way below the starling of two others, which appear to be of little or no use or consequence to navigation.

Question 3d.—If by stopping up arches, or raising the bed of the river under the arches, which arches will be best to be stopped up, or the beds under them raised; and what will be the expense thereof?

Answer.—The addition of water-way is altogether made under the great arch; and if the reduction were to take place there alone, it would totally defeat the purposes of the committee in doing service to the navigation, by the opening thereof; it is therefore I propose to do only a part here, such as is consistent with those views, and the rest under such other arches as will admit thereof without prejudice.

For the particular manner of executing this scheme, I must refer to a drawing (see plate I.), containing two sections of the water-way under London Bridge, the first figure shewing the water-way as it was before the alteration; and afterwards, as it was at the beginning of February, 1763: figure 2d shews the water-way as it is intended to be after the alteration now proposed.

The

The abstract of the first section, figure 1. is as follows :

	Feet, superficial.
The area of the water-way below the starlings, before the alteration, was	2073
The increase of water-way by removing the solid under the great arch, and by the subsequent increase of depth,	861
The diminution of water-way by stopping up the two locks next the south shore,	154
The difference is the increase of water-way,	707
The sum is the water-way after the alteration, the beginning of February, 1763,	2780

It therefore appears, that in order to restore the water-way, and of consequence the water-works, to what they were before the alteration of the great arch, the area of the water-way below the starlings, such as it was the beginning of February, 1763, must be reduced by 707 superficial feet; and in order to do this without prejudice to the navigation, I would propose it, to raise the bed of the river under the great arch, so as to be eleven feet at its highest part under the top of the starlings, in which case it will have the same depth of water as the draw lock, which was accounted the most useful for large craft before the alteration; and which, as well as the great lock when the water-way is restored, will never have a less depth of water than five feet at low water.

2dly. By advancing the starlings into the great lock, so as to double the fence, as proposed to the committee by Mr. PHILLIPS, a further reduction will be effected, and this being done three feet on each side, will still leave a water-way under the great arch in breadth fifty-two feet, which will be very sufficient for the craft.

3dly. I find there are four locks, whose depths exceed that of the draw lock, all of which are, on account of their widths, unfit for the passage of the larger craft. I therefore propose to raise the beds of those locks one foot higher than the level of the draw lock and the great lock. *St. Mary's* lock was justly accounted the best for large craft before the alteration, being the widest (viz. nineteen feet in the clear) and one of the deepest, viz. fifteen feet below the starling, that is four feet deeper than the draw lock; this depth of fifteen feet I apprehend to be totally unnecessary, and rather tending towards the insecurity of the bridge; but as the preserving one lock deeper than the rest, may possibly on some occasion be useful, I propose raising the bed of *St. Mary's* only two feet, in which case it will be thirteen feet below the starlings, that is two feet deeper than what is proposed for the great lock.

4th. As Long Entry and Chappel locks, which lie between *St. Mary's* and the great arch, appear to be of less use than any of the rest, being both narrow and shallow, and by their indraft tend to bring the craft foul upon the intermediate starlings, without a possibility of their passage, I would therefore propose those to be stopped up to starlings' height, the same as the first and second locks on the south side now are; and that the craft may not be entangled with those locks or their starlings, but always find a passage either through the great lock or *St. Mary's*, I would propose fender piles to be drove at about three feet distance in a circular manner, from the upstream point of the starling of the great arch, to the upstream point of the starling of *St. Mary's*, as represented in the draft fig. 3, at R.; those piles to be well braced, and their heads capped over about two feet above high-water mark.

These things thus done, the account will stand as follows:

PROPOSED REDUCTIONS of the area of the water-way below the starlings.

	Feet, superficial.
By raising the bed of the great arch, - - -	314
By extending the starlings three feet on each side, - - -	66
By raising the bed of little lock, - - -	52 $\frac{1}{2}$
By ditto of <i>St. Mary's</i> , - - -	38
By shutting up Chappel lock, - - -	50
By ditto Long Entry, - - -	66 $\frac{1}{2}$
By raising the bed of Non-such lock, - - -	60
By ditto of Roger lock, - - -	27
By ditto of the fifth lock, - - -	37 $\frac{1}{2}$
Water-way to be reduced, - - -	711 $\frac{1}{2}$
Increase of water-way as before stated, - - -	707
Overplus, - - -	4 $\frac{1}{2}$

Now there will still remain an increase of water-way above the starlings by the removal of the shaft of the middle pier; but as the effect of this can only take place while the water is above the starlings, when the water-way is at the greatest: the effect upon the water wheels thence arising does not appear by computation to be above $\frac{1}{300}$ part of the whole, which will be much more than compensated by the above overplus of 4 $\frac{1}{2}$ feet below the starlings.

It is possible, notwithstanding the attention I have paid to this matter, that some circumstances may intervene, which have not occurred to my consideration; but I apprehend that none can, which may not be compensated by raising the bed of *St. Mary's* lock to the same height as the great lock: to which I can see no objection, if experience should shew the same to be necessary.

The easiest, cheapest, and most effectual method of raising the beds, not only of the great lock, but of the others, is, by throwing in rough stones, so as to form a slope both ways, the interstices of which in time will fill up with gravel and the fullage of the river, and become as compact and durable as a rock. The heaviest, roughest, and largest stuff, is best adapted for this purpose, and none better than large *Kentish* rubble; but for want of a sufficient quantity thereof, *Portland* or *Purbeck* rubble may be used, provided it is more large in proportion, as it is less sharp and heavy. For the particular application thereof to the great arch, I refer to the drafts, figs. 4, and 5.

N. B. If the following method should be thought more eligible; instead of raising the bed of *St. Mary's* lock, the first open lock next the water-works may be stopped up, by two pair of gates pointed westward; forming a navigable pen lock between them; which would enable such craft as can row or sail against tide to pass the bridge upward on tide of ebb, without waiting for tide of flood. And in this case the stopping up of Chappel and Long Entry locks may be dispensed with. In what extent this scheme may be of advantage to the navigation, I am not enabled to judge, but am of opinion, that if not of material use, what was first laid down is the most eligible, as the gates would need frequent repairs.

Question 4th.—If by improving the old wheels, or adding new ones, which will it be best to improve, or where add the new ones; and at what expense will this be done?

Answer.—I apprehend, as was mentioned before, that all the wheels may be improved, but the wheels in the first and fourth arches from the north shore are the most susceptible thereof, and the most want it; if any wheel were to be added, it should undoubtedly be in the fifth arch, which, though a capacious lock, is not much used by craft going down on tide of ebb, on account of the shipping commonly lying before it; but as I look upon it to be more eligible to restore the effect of the water-works by the more certain, and perhaps less controvertible method above described; I have not made estimates for these erections and improvements, to do which, with any tolerable degree of exactness, (being very compounded) would take up some time.

Question:

Question 5th.—If arches are stopped up, or beds raised, what effect will this have upon the channel of the river?

Answer.—If done in the manner before proposed, no sensible effect of any kind whatever.

Question 6th.—What effect upon the channel of the river has been produced by opening of the great arch, and by what means are the inconveniencies, if any, to be removed, and particularly with respect to what is alledged in the memorial of the Waterman's Company?

Answer.—Upon opening the great arch, the water finding a more free and open passage there than in any other part of the bridge, the main current would, of course, be drawn thither, and in consequence, acting more strongly upon the bed of the river than before, some thousand tons of matter appear to have been moved by the action of the tides setting in each way, above, between, and below the starlings; the most gross and heavy parts subsiding as soon as the strength of the stream is spent, form shoals or banks of matter both above and below bridge; yet such banks, though encreased by the fresh action of the great arch, appear, in a great measure, to have been formed before, by the rapidity of the current setting through the arches; and I remember to have seen the shoal above bridge many times dry before the alteration took place, and if I am not mistaken that below likewise. The present channel below bridge, stands quite fair to the great arch, and has about $4\frac{1}{2}$ feet navigable water over it at low still water; but above bridge the case has been more untoward, for the body of the former shoal happening to lie somewhat to the south of the direction of the great lock, the new-formed matter has, in a great measure, lodged itself in addition to the north side thereof, which has of consequence thrown the main channel of the river considerably more to the north side, so that the current, on tide of ebb, making a sudden turn near the bridge, has rendered it difficult for the craft to make the great arch, notwithstanding the great enlargement of its width. The effect of this grievance will, in some measure, be remedied by the alterations proposed in the bridge itself, because the set of the tide being less strong to the great arch, as well as more equally all over the bridge, the direction of the current will be less diverted towards any particular place: towards this end the stoppage of Long Entry, and Chappel locks will also contribute; for being situated between two of the principal arches, the balance will be preserved, and the current less diverted in its passage through either of them. This, together with the fender piles before these two locks, will direct the craft, so that they cannot fail of hitting
one

one or the other, when there is water enough over the shoal above ; but at or near low water, I don't apprehend that any thing less than taking the whole shoal away, down to the depth of the main channel, can procure a true set of the tide ; however, it may in a great measure be remedied, by making a passage or channel through the shoal, which channel, to prevent as much as possible the effect of the superior indraught of the main channel from acting upon it, should be exactly in the direction of the great arch, but its west end declining a little to the southward ; this new channel should be at least four feet deep at low water, and as wide as the great arch, and I know no better method of performing it, than by the ballast lighters ; it will also be advisable to widen and deepen the present channel through the shoal below bridge, so as to make two and a half feet more water over the same but this will be a much less work than the former.

I come now to consider the matter of the memorial of the Watermen's Company.

I apprehend, when all is finished, the great lock will be found most useful to small as well as large craft, as no boat can catch upon the starlings there, being wide enough for most vessels to go through sideways.

I apprehend, the small locks most used by small boats should be planked or lined, which will be of service to the starlings, and at the same time prevent boats from catching upon the irregularities of the piling, in which, I apprehend, consists the greatest danger in passing London Bridge on tide of ebb, with the water below the starlings.

I am informed there are several stumps of piles in several of the locks ; but while I was making my observation, there was always too much water to see them ; it would be right to saw or cut them off with a large chisel made for the purpose, but not to draw them or drive them down.

Respecting the bank opposite Fishmonger's-Hall ; the methods foregoing tend to procure a true set of the tide through the great arch ; but I know of no bank, either about or below bridge, that is of material consequence to the water-works ; the current sets over from the water-works towards the great arch, not because it is impeded by a shoal but because it finds a readier passage that way.

REFERENCE

REFERENCE to the plans annexed.

Plate I.

Fig. 1.—A, The shaded space shews the pier, starling, and bed of the river, which, before the alteration, were solid, but which, at the beginning of February, 1763, were converted into water-way.

N. B. The light shaded spaces shew the dimensions of the water-way in each lock, taken at such part where the bed of the lock is highest. The figures above the spaces are the widths of the respective locks, (the piers and starlings between them being omitted), the figures beneath are the depths taken from the surfaces of the starlings at the place where the depths are least.

E E are two locks—the first and second from the *Surry* shore, which, before the alteration, were open, but which were closed up by dams of piles, in the beginning of February, 1763.

Fig. 2.—The light shaded spaces shew the intended dimensions of the water-ways of the respective locks, as they will be after the proposed alteration, the widths, except the great lock, are the same as fig. 1. and the depths are specified beneath.

C C C C C—Solids, added in order to raise the depths of the respective locks.

D D—Two locks to be closed up with dams of piles to the height of the starlings.

E E—Two locks already closed, which are to remain so.

ff—Solids, to be added to strengthen the starlings within the great arch, three feet thick on each side.

N. B. Both these sections suppose the water-ways laid together, both above and below the starlings, and all the solids removed, except such as are the subject of the alterations.

The measures differ something from those before taken, by reason of their being taken at different places.

Fig. 3.—R shews the disposition of the fender piles, extending from the great lock to *St. Mary's*, to prevent the craft getting foul of the two intermediate locks.

D D—Locks which are to be closed up as before stated in fig. 2.

E E—The same as fig. 2, and C, the six locks, to be raised as in fig. 2.

The names of the different locks in this figure, and the numbers, which are the same in fig. 1 and 2, will point out the names in the latter figures.

Fig. 4.—Plan, and fig. 5. section of the proposed alterations under the great arch.

H—A body of *Kentish* rubble for lining the bottom of the river under the great arch, to resist the action of the water, and for raising the bed of the lock for the service of the water-works, leaving five feet depth of water over the crown of the dam at low water, for the service of the craft.

I—Blocks of *Portland* stone, eight feet long up and down stream, and two feet six inches thick for capping the top of the rubble.

K K K—Ground pier of larger rubble stones than the rest, for supporting the smaller until a compleat bed is formed.

L L—Fig. 5. dotted lines, shewing in what manner the starling of the great arch may be enlarged three feet on each side.

APPENDIX.

INVESTIGATION of the answer to question 1st, viz.

1st. **I**N what degree, at a monthly average, is the natural power of the water, and effect thereof, upon the wheels of London Bridge water-works diminished, by the removal of the pier, and opening of the great arch?

An exact solution of this question is, perhaps, impossible, on account of the very great variety of circumstances that affect it; yet from the great number of observations that I have made upon the bridge and water-works, relative thereto, by attending to the most material and leading circumstances, and by repeating such as are of small account, or whose effects are likely to balance each other; I flatter myself that what is here offered, will be found sufficiently near the truth to fulfil the purposes for which the question was proposed. And here I must premise this principle, that where water moves through confined passages, which occasion a sensible pen or difference of elevation of their surfaces, above and below the passage, the water moves through the same as one column, that is, nearly the same at bottom as at top, abstracted from friction; and therefore, that an increase of depth is of equal consequence with an increase of width. This appears from reason to be the case, since every part of the effluent column is put in motion by a column of the same height, viz. one whose height is equal to the difference of the two surfaces; this is also confirmed by experience, and in the present case is remarkable, since it was the action of the effluent column upon the bottom of the river, that has removed such a large quantity of matter from under the great arch.

On this account I have taken the section of all the water-ways below the starlings afresh, and as I did not confine myself to any particular part of the locks, but where I found the shallowest part, there I took the width between the starlings, this occasions some difference between these and former measures.

Plate 1. Fig. 1.—Is a section of the water-way at London Bridge, in which the dark shaded place A. represents the solid of the pier, starling, and ground upon which they

they stood, before the alteration; which solid being converted into an opening, and the first and second arches from the south shore being closed up to starling's height, shows the section of the water-way the beginning of February, 1763, from whence it appears, that when the surface of the water is at the heights hereunder expressed, the sum of all the water-ways, taking width and height together, was

	3½ Feet above the Starlings.	At Starling's Height.	3½ Feet below the Starlings.
Before the alteration, - - -	4365	2524	1656
Beginning of February, 1763,	5245	3231	2244

Within these limits the principal part of the business of the water-works is on an average performed. The mean proportion therefore of the increase of water-way, above and below the starlings, will stand thus:

At 1 foot 9 inches above the starlings, as 3444 to 4238.

At 1 foot 9 inches below the starlings, as 2090 to 2737.

Let us now consider what alteration will be produced in the motion of the water through the openings enlarged in the proportion above specified.—London Bridge may, in some measure, be considered as a sluice, through the openings whereof the water of one part of the river is discharged into the other, moving one way or other according as each surface is respectively higher or lower.—Now, if the water's passage is enlarged, the water will be discharged sooner from the higher to the lower; but not so much sooner as in proportion to the increase of opening, because that would require the same velocity to be continued, and consequently the same difference of elevation of surfaces to be preserved; which cannot be, unless a greater quantity poured into the pool below in the same time, could run off without swelling to a greater height, which is impossible. The difference of surfaces therefore being lessened, the velocity of the water will be diminished, which depends thereupon, and the time proportionably lengthened. On the other hand, since the quantity of water, sooner or later, must pass through every section of the same river, if any section is enlarged, the velocity will be diminished, and diminished in the same proportion as the section is increased, where the water has a free passage and goes off as it comes, without being pent up; but when, being pent up, a part of the obstacle is removed, the velocity of the issuing water

water is diminished on the account before mentioned, but not so much diminished as the section is increased, because, were that the case, the head of accumulated water would be as long in running off through a larger opening as through a smaller, which is contrary to our first position, and to matter of fact. The enlargement of the water-way therefore acts two ways; that is, partly by diminishing the time in which a given head is run off, and partly by diminishing the velocity of the water so issuing; and since each of these principles has an equal claim, they will be separately and inversely, as the lesser water-way to a mean proportional between that and the greater.

Now, if the effects of these two principles upon the water-works, followed the same proportions, they might be both considered together as one; and the diminution of effect of the water-works would be simply as the increase of water-way; but this they do not, for the diminution of effect on account of time will be as the diminution of the time simply; but the diminution of effect on account of velocity, will be as the square of the water's velocity; for the wheels will not only diminish their velocity in the same proportion as the velocity of the impelling fluid diminishes, but their velocity will be further diminished in proportion as the impulse is weaker thereupon, and the impulse being weaker in proportion as the diminution of velocity, the velocity of the wheels acting against the same load, will be diminished in duplicate proportion, that is, as the squares of the velocity of the water, as I have had formerly an opportunity of proving by many experiments.

The effect therefore of the enlargement of water-way, upon the water-works, being compounded partly of a simple, partly of a duplicate proportion of the enlargement of the water-way, will be in a proportion between the two, that is, the proportion which is called sesquialtera.

Now, taking the sesquialtera proportion of the above-mentioned enlargements, viz.

	Direct proportion.	Sesquialtera.
Above the starlings	- 3444 : 4238	3444 : 4702 i. e. 1 : 1.365
Below the starlings	- 2090 : 2737	2090 : 3120 1 : 1.500
the diminution of the effect of the wheels will therefore be,		
	At a medium above the starlings, as 1.365 : 1	
	At a ditto below ditto - - 1.500 : 1	

But the general proportion upon the whole will be compounded of the above proportions, and of the times of the continuance under the above proportions respectively.

At

At a neap tide, February 8th, the wheels at a medium worked five hours, and at a spring tide, February 15th, $6\frac{1}{2}$ hours. The respective times above and below starlings, were as follows :

				Above the starlings.	Below the starlings.
Neap tides	-	-	-	$1\frac{3}{4}$ hours	$3\frac{1}{4}$ hours
Spring tides	-	-	-	3 ditto	$3\frac{1}{2}$ ditto
				—	—
				Sum $4\frac{3}{4}$	$6\frac{3}{4}$

Now, as it is the proportion, and not the absolute quantity of time, above and below the starlings, that comes under the present consideration, it is of no material consequence, though the length of time during which the water wheels continue at work each tide should differ sometimes from those observed, provided the proportion of the time above the starlings to that below is nearly the same, which we may reasonably presume : Multiplying therefore the number 1.365, expressing the proportional difference of the effect of the wheels while the water is above the starlings, by the sum of the times $4\frac{3}{4}$, we shall have 6.48375 ; and in like manner, multiplying 1.5, the number expressing the proportional difference of effect below the starlings, by its correspondent sum $6\frac{3}{4}$, we shall have 10.125.

Now $4\frac{3}{4}$	6.48375
$6\frac{3}{4}$	10.125
—	—

Sum of the times $11\frac{1}{2}$, the sum of the products 16.60875 ; and dividing the sum of the products by the sum of the times, we shall have 1.444, which will express the mean proportion of effect above and below the starlings, the proportion of time considered and included ; which proportion of 1.444 to 1, or 1444 to 1000, would be the proportion of the power of the water before and since the alteration, did not some other cause intervene, which, though of less consideration, may not inconveniently be brought to account.

The water-way of the great arch being much more open and free than the rest, it is reasonable to suppose that the velocity of the water is less impeded by friction than in the others, which will increase the proportional discharge by the great arch, and in consequence increase the above proportion. I found by experiment, that when the water was at its medium workable height below the starlings, its velocity was $\frac{1}{5}$ quicker through the great arch, than through the rest at a medium ; but as the difference when the water is above the starling will be considerably less than as above specified, and

and yet it will be something, I therefore take $\frac{2}{3}$ of the above quantity, that is, $\frac{2}{3}$ for a medium of the whole. Now, $\frac{2}{3}$ of 1444 is 193, which, being added, make 1637 : 1000, for the proportion once corrected.

2dly. On account of the increase of water-way at London Bridge, I find that the tides rise at a medium, four inches higher above bridge than they did before ; and that at a medium the rise is from low water above bridge, about eleven feet ; so that the body of water is increased in perpendicular height, and at least in quantity, by $\frac{1}{3}$ part of the whole. Now this additional quantity will act upon the wheels in the same manner as the main body, that is, partly by increasing the velocity, and partly by lengthening the time ; its effects will, therefore, be in a sesquialterate proportion of the quantity, that is, nearly $\frac{1}{3}$ part of the whole, and of course will lessen the number 1637 before stated ; therefore $\frac{1}{3}$ part of 1637, which is 71, being taken away therefrom, the remainder will be 1566 ; so that 1566 to 1000, will express the proportion in which the natural power and effect of the water upon the water-wheels is diminished by opening the great arch, exclusive of such causes and irregularities as cannot be brought into the account.

Ever since the year 1756, a daily register has been kept at the water-works, containing the time of high and low water, the height to which the tides rose above bridge, with the number of strokes of flood and ebb that was made by each pump of the westernmost or first wheel in the fourth arch. To this book having, by permission of the company, had free access, I have endeavoured to extract therefrom such materials as might ascertain their average performance, before and since the alteration of the great arch : this I did by extracting three adjoining of the best spring, and three adjoining of the worst neap tides, during the course of a month, at each quarter of the year ; the months were March, June, September, and December, which take in the equinoctial and solstitial tides, and the summer waters will be balanced against the winter ; so that the average tide for each year was collected from the medium of forty-eight tides, critically chosen at such seasons as were most favourable, and most unfavourable for the performance of the engines. An abstract of which is as follows :

				Number of strokes.
Average tides for the latter half of the year	1756			2803
for the year	-	-	1757	2888
do.	-	-	1758	3029
Carried over				8720

			Brought over	8720
Average tides for the year	-	-	1759	3215
do.	-	-	1760	3099
do.	-	-	1761	3142
for the first half of the year			1762	2998

Sum 21174

Mean 3025

					Number of strokes.
Average tide for July	-	-	-	1762	2846
August	-	-	-	do.	2448
September		-	-	do.	2193
October	-	-	-	do.	2121
November		-	-	do.	2090
December		-	-	do.	1689
February		-	-	1763	2248

From the above it appears, that for six years preceding the alteration, the average performance of this engine was 3025 strokes per tide.

That from the time of beginning to take away the starling, the performance gradually lessened, till December, when it fell remarkably short, and as remarkably increased in the month of February; which irregularities were undoubtedly owing to the remarkable drought in the month of December, preceding the frost, and at a season when the tides at sea naturally run short, and the other to the remarkable tides and floods that succeeded the frost; so that balancing those two months against each other, the average will be 1968; but if we take the four months of October, November, December, and February, since the alteration, the average will be 2037. So that, comparing the average performance of those engines, before and since the alteration,

they will be as $\begin{cases} 3025 \text{ to } 1968, \text{ that is as } 2000 \text{ to } 1300. \\ 3025 \text{ to } 2037 \end{cases}$ 2000 to 1346.

but by calculation as 1566 to 1000 2000 to 1277.

Hence

Hence it appears that the deficiency, as obtained by the company's register, being at most 700 in 2000, is not so great as results from calculation, which amounts to 723, whereas from considering the great proportional increase of friction in the works, when acted upon by a smaller power instead of a larger, one would have expected the difference to have been on the other side.

But this I apprehend to be balanced, and perhaps more than balanced, by the following circumstance :

It has been already proved, that the wheels work slower than before in a duplicate proportion of the difference of the water's velocity ; suppose this, for argument's sake, to be $\frac{1}{4}$; now if the wheels work at a medium $\frac{1}{4}$ slower than before, the water will move $\frac{1}{4}$ slower through the pipes, which amounts (respecting the engine) to the same thing as if the area of the pipes were made $\frac{1}{4}$ larger : in consequence whereof the water moving to its place of destination with greater facility, will not require so tall a column to impel it, so that the water will not rise to so great a height in the stand pipes, and in consequence the engine acting against a less column of water will tend to revolve faster, and in so doing will, I apprehend, in the present case, produce an equivalent to the greater proportion of friction.

1763.

J. SMEATON.

ESTIMATE for the works specified in answer to question the 3d.

To 3000 ton of rubble stone for raising the bed of the river under the great arch, and securing the same, at 10 shillings per ton,	-	-	-	-	-	£1500	0	0
To 320 feet running of additional wharfing to the starling of the great lock, at £4	-	-	-	-	-	1280	0	0
To 1040 cube feet of <i>Portland</i> blocks, for capping the crown of the dam of rubble under the great arch, laid in place, at 3s. 6d.	-	-	-	-	-	182	0	0
To 240 feet superficial of plank piling, for stopping up Chappel and Long Entry locks, at 5s.	60	0	0					
To 2000 ton of rubble, for raising the beds of the five other locks, at 10s.	-	-	-	-	-	1000	0	0
To 4200 cube feet of fir timber, to make the fender piles before Long Entry and Chappel locks, including brace piles and braces, every thing fixed in place, iron work included, at 4s. per foot,	-	-	-	-	-	840	0	0
						4862	0	0
To contingencies upon the above accounts, at 10 per cent.	-	-	-	-	-	486	0	0
						5348	0	0
						Total	£5348	0 0

N. B.

N. B. It will take 2000 tons of rubble to line the bed of the river under the great arch, for the security thereof. The second article is chiefly calculated for the same purpose; and the last article, being wholly for the service of the navigation, which may be applied or not after the other works are performed, as the use or necessity of the thing shall direct. These articles being deducted from the above estimate, there will remain £1742 to be expended on account of the water-works; which, with its proportion of contingency, comes to £1916. The necessary repair of the starlings, on account of the damage done by the ice, is not included in the above estimate.

The REPORT of JOHN SMEATON, engineer, concerning the state of the great arch of London Bridge.

HAVING carefully viewed the piers and starlings, and taken soundings of the depth of water, both underneath and for some space both above and below the great arch of London Bridge, before, at, and after low water, on Friday, the 25th July, 1766, I have the pleasure to assure the committee, it does not appear to me, that either of the piers, or the arch dependent thereon, has given way in the smallest degree, nor does there appear to be any crack or settlement therein, by failure of the foundation, or otherwise, that I observed; and though a part of the out-works of the south pier has suffered some derangement by the continued action of a very rapid and powerful current, yet, by the seasonable application of 200 tons of rubble stones, it appears to be secured for the present, so that I don't find the structure in immediate danger. Having said thus much for the satisfaction of those who may have supposed otherwise, I will now proceed to report the result of my own observations, as to the causes of the present failure, and what appears necessary for further security: but first I must premise, that

When I was called upon, in the beginning of the year 1763, I found the depth of water under the great arch, at low still water, to be twenty-two feet, the current making hourly depredations upon the starlings, the south-west shoulder of the north pier undermined six feet, and the original piles, upon which the old works had been built, laid bare to the action of the water, and several of them loosened. In this perilous state, when a settlement of that pier must necessarily have taken place in a few days, I proposed the only remedy I knew of, that was likely to be attended with success in circumstances so pressing, viz. that of securing the bed of the river with a body of rubble stone, upon which the said angle was under-pinned, and so far secured, that it has never yet shewn any defect. It was also thought proper to raise this body of rubble so high as to pen up the water for restoring London Bridge water-works to the same power as before the alteration, and to defend the starlings, next the great opening, by an *additional* out-work of three feet broad, on each side, surrounding the former casing; which matters were fully set forth in my former report, dated 18th March, 1763.

On sounding at low still water, on Friday 25th, I found no where more than eleven feet water, and in general not above eight feet, immediately under the great arch, but above and below, in a line, and at the points of the starling, I found twenty-four and
twenty-five

twenty-five feet water below, and from twenty-two to twenty-six feet above bridge. I also found in going downward, in the direction of the stream, at the distance of about thirty-five or forty feet below the points of the starlings, the water to deepen to thirty-three feet; and at seventy or eighty feet, which was the deepest place, thirty-eight feet. On the upstream side of the bridge, about fifty feet above the point of the starlings, I found twenty-eight feet water.

From the above soundings it appears evident, that from the continual wear of the very powerful and rapid current which sets through this arch, that the bed of the river, above and below the points of the starlings, has been worn away to a much more considerable depth than it was in the year 1763; in consequence of which the bed of the river, from the points of the starlings upward and downwards, forming a slope too great for the rubble to lie upon, when impelled by so strong a current, the skirts of the rubble will naturally slide into the cavities; this, in consequence, has impoverished the body of rubble immediately under the arch, which it did on the south side so as to loosen the piles for about twenty feet in length, of the additional casing that had been driven into, and had their fixing in the body of rubble; but which, by a timely supply of same material, are now made firm, and this part of the body of the bed of rubble is as high as any of the rest, so that no immediate danger is hence to be expected.

The reasons why the failure of the outward casing happened on the south side, I apprehend to be the following:

1st. That as it was the north pier that complained in the year 1763, the principal attention would naturally be directed to that side, and, in consequence, the best and largest rubble be deposited there.

2d. From the natural set of the current of the river, which for the space of about 100 yards above the bridge sets obliquely over from the north side to the south, and will, in consequence, strike against the north face of the south starling of the great arch, this cross set of the tide is rendered still more oblique by the particular situation of the arches that are stopped up. When my report of 1763 was made, I found the two locks next the *Surry* shore stopped up, and advised the two small locks next the great arch, on the north side, called Long Entry and Chappel locks, to be stopped up likewise; this, with the proposed alterations under the great arch, and the raising the beds with rubble to a certain height, of five other locks, which I found unnecessarily deep, (all which were specified in a draught attending my report), appeared, in my opinion, sufficient to restore
the

the water-works to their former power. Upon my view, on Friday the 25th, I observed that the two locks next the *Surry* side were open, and was informed that none of the beds of the five locks had been raised, but that in lieu thereof, the fifth lock from the north shore, had been and remains stopped up. Now, if all the locks on one side of the great arch were stopped up, the current would be obliged to make its way towards the open side; the stopping up, therefore, of the fifth lock, on the north side, and the opening of two upon the south side, must necessarily conduce to carry the current more obliquely towards the south side than it would naturally do; whereas the stopping up of the two arches proposed by me on the north side, would have been no more than a counter balance to those I found stopped on the south side. I did, indeed, suggest in my former report, that in case it should be thought eligible for navigation, two pair of pointed gates, so as to form a navigable pen lock, should be placed in the fifth arch from the north side: in which case, the raising of the bed of *St. Mary's* lock, and the stopping up of Chappel lock, or Long Entry, might be dispensed with; but this I did not recommend as preferable to my first scheme, unless more eligible on account of navigation. Upon the whole, it is to be wished, for the sake of security to the bridge, as well as navigation, that some equivalent could be formed to the water-works, so that all the arches might be unstopped; the great arch remaining as it is.

I now come to advise what is further necessary, in my opinion, to be done for the security of the bridge, which principally consists in guarding against the derangements that probably will arise from the deepening and wearing away of the ground above and below bridge; and for this purpose I would advise, that, with all possible dispatch, a further quantity of *Kentish* rubble be deposited between and at the four points of the starlings of the great arch, so as to lessen the too great depth and slope of the bed of the river and of the rubble, to the end that the rubble so deposited may not work down into the pools; it would be adviseable so far to lessen the depths thereof, by dropping in rubble, as to make a firm footing for the rubble that lies immediately more contiguous to the piers and starlings; further than this would be rather detrimental than useful.

After all, it will be necessary that the condition of the rubble bed should be frequently examined, and to have always in readiness a quantity of rubble to supply such deficiencies as, from time to time, may happen; for, though this method will, like the starlings and the rest of the ground-works of this bridge, need occasional temporary supplies, yet, being duly attended to, there is sufficient reason to suppose that it will prove a lasting support; and, if imperfect, yet deserves the greatest attention, because I do
not

not know any practical method by which the great arch of this bridge, so founded and so circumstanced, can be maintained and supported without incurring much greater expenses with less certainty; and when, by the disposition of rubble, the cavities above and below are hindered from pooling, and the foot of the rubble bed, within the starlings, supported thereby, and the whole by time consolidated, it may be expected that the repairs of this part will be very inconsiderable.

J. SMEATON.

London, 28th July, 1766.

To the right honourable the Lord Mayor, Aldermen, and Commons, in Common Council assembled.

MY LORD AND GENTLEMEN.

IN answer to the order of common council, of the 13th day of March, in which I am desired to *take into consideration the state of London Bridge; of the navigation under the same, and of the London Bridge water-works; and also the proposed alterations suggested in the committee's report, and to give my opinion upon the same*; I must beg leave to refer the honourable court to my former report, of the 5th of February, wherein is contained the most material part of what I can observe upon the subject.

I, therefore, consider what I now further offer as supplemental thereto.

Respecting the state of London Bridge, I look upon its greatest weakness to be in its foundations, being chiefly built upon piles, sawn off above low water mark; and this construction considered, I am of opinion, that the less the fall and velocity of the water is, in passing the bridge, the less subject those piles, together with the starlings and other works for defending the piers, are to get out of order, and into disrepair, and consequently the *less fall*, the greater security to the bridge.

The alterations suggested to the committee (as appear in my paper above referred to), directly tend to diminish the fall and velocity of the water; and, therefore, so far as that difference goes, it is in favour of the foundation of London Bridge.

I apprehend this honourable court is, by the act of parliament for the alterations of the bridge, obliged to keep up a head of water for working the engines as effectually as they were worked before the alterations; and, if so, I am clearly of opinion, that the fall and velocity must be maintained greater than they will be, in case the alterations *suggested in the committee's report*, are carried into execution; and, therefore, that consistently with the maintenance of power to the London Bridge water-works, the fall will be reduced, by the proposed alterations, as much as it can be, and for this reduction that the grant of the further arches may, in some measure, be considered as a compensation for the loss of power that they would otherwise sustain by the other parts of the proposal.

With

With respect to the navigation immediately under or through the bridge, as nothing can be more clear than that whatever tends to diminish the fall and velocity of the water there, must be of benefit to the navigation, the only question that can remain on this point is, whether, by diverting the navigation from the first and second arches on the *Surry* side, it will lose any thing that is material.

The particular uses of these arches to navigation is matter of experience and practice which I have not had ; but, in my own opinion, I apprehended them to be in this respect of very little benefit, and am the more confirmed in this opinion, by having found them both stopped up, (and the only ones that then were so), for the assistance of the water-works, when I was called upon in this affair, in the year 1763, and the reason then given was, that those two arches were looked upon as the least useful of any in the bridge, for the purpose of navigation ; the difference, therefore, in point of navigation, immediately under the bridge, seems, upon the whole, in favour of the alteration proposed ; but, if we consider the navigation of the *Thames* above bridge, I am of opinion, that were the fall at the bridge considerably reduced, *by any means whatever*, the navigation of that part of the river would be *materially* affected.

It is difficult at this time to determine, whether the bed of the river *Thames* was as high above bridge before London Bridge was first erected, as now it is ; and whether the stoppage of the water at the bridge, acting as a dam, was an *expedient* to retain more water in the river at low water over those shoals for the sake of navigation ; or whether this stoppage arising from the construction has, in its *effects*, occasioned the fullage of the river gradually to gather, and the bed to rise nearly in the same proportion as the water's surface at low water is kept higher ? however this might be, 'tis certain the bed of the river above bridge, is now, in *proportion*, *higher* than it is below bridge.

If London Bridge were, therefore, to be taken away, the river would become so shallow above bridge, at low water, that the navigation would be greatly impeded for hours each tide.

If this difference of bed was *original*, we must expect it to remain ; but if an *effect*, the cause being taken away, the river would gradually restore itself ; but as this might probably take up seven or eight hundred years, (the time it has probably been gathering), the work of restitution would go on far too slowly to answer the demands of the present generation.

That

That a stoppage at London Bridge, in the present state of the bed of the river above bridge, is necessary to the present navigation thereof; and that it cannot greatly be reduced, without detriment, is more than speculation. The ill effects were experienced during the time that the bottom of the river was gulled underneath the great arch to the depth of above twenty feet at low water, when, by means of so great a water-way, the tide-water was discharged so much more speedily, as not only to prove greatly detrimental to the power of London Bridge water-works, but also to the navigation of the river above bridge.

If, therefore, the keeping up of a certain head of water be necessary to the navigation above bridge, and to enable this honourable court to acquit themselves of what is enacted respecting the water-works; if the water-works will, by agreement, (in consequence of availing themselves of the additional arches), be contented with *such a head* of water as will subsist after the dam proposed to be removed, and the other alteration suggested made; then will this honourable court avail itself of all the reduction that the case, in all its circumstances, will admit of; and as it appears that some head of water must be kept up and maintained, not only for the water-works, but for the navigation, then the more *useful purposes* this head of water is applied to, the more beneficial it will be to the community.

The petitioners set forth, *that wheels under the four arches in their possession, would not act with the same velocity, at any time, as they did before the alteration of the bridge, when two arches were laid into one*: if this allegation is true, then it will follow that the head of water has never been so great, since the alteration, as before. And on this occasion I must, in justice, declare, that the several matters contained in my report of 1763, on purpose to restore the head of water, have never been fully put in execution; and that, except what has been done under the great arch, no part of the directions therein contained has been pursued, except the stopping up of Long Entry and Chappel locks; the doing whereof has since been complained of, as making an eddy; and that, in lieu of other alterations by me suggested, the fifth arch was stopped up as it now remains, and with which, I suppose, the company were contented; but which, in my opinion, was not equivalent to the head of water that would have been gained, had the several alterations proposed by me taken place. Hence it most evidently appears, that if the honourable court should not confirm the proposed agreement between the committee and the company, instead of reducing the head of water still further than it now is, by the further proposed alterations, the court will be obliged to support a greater head of water than has ever subsisted since the removal

removal of the old pier under the great arch; which, as has already been said, is what, by all means, ought to be avoided, both on account of the bridge and of the navigation.

As the Long Entry and Chappel locks were stopped up in consequence of the directions in my report of 1763, it may not be an unseasonable digression to say a word or two on that subject. It appeared to me from computation, that in order to restore the head-water, as prescribed by the act, it was necessary to stop up some of the locks, and raise the bed of others. In order to specify which locks should be stopped up, I enquired which of them were least useful to navigation; and, among others, Long Entry and Chappel Locks were mentioned, as being both too narrow and too shallow. In order to destroy, as much as possible, the effect that might be produced by stopping up of locks on one side of the great arch, more than of the other, I proposed to have stopped one of the locks next to the great arch, on the Surry side, which, together with the two locks that I found stopped, (and proposed to have remain so), next the Surry shore, would have made three stopped arches on the Surry side, and two on the London side; but, instead of this, the dams on the Surry side were removed, and the fifth arch from the London side stopped up, which made three stopped locks on the north side, and none on the other, by which means the balance of current on each side of the great arch not being preserved, the current of the great arch must, necessarily, tend to that side where it meets the least resistance; that is, towards the two adjacent stopped arches, and form a greater eddy there than it would have done, had its tendency been equal both ways.

In my last report, I have declared it as my opinion, "that three locks being stopped up on the north side of the great arch, and none on the south, is the greatest artificial cause of the eddy complained of, and that the changes proposed are the most likely and easy means to remedy the same."

It must not, however, be expected, that the eddy of the great arch will be wholly removed by taking away the dams from the locks above-mentioned; for so far as it depends upon a superior strength or column of water, penetrating into the body of more still water below, it must be expected always to remain.

Upon the whole matter, I am clearly of opinion, that considering the advantages to the security of the bridge, arising from an easement of the fall below, and the being clear of the pipes above, to the navigation through the bridge, and also to the naviga-

tion of the Thames above bridge, this honourable court cannot do better than confirm the proposed agreement, which the committee have formed with the proprietors of the water-works; it being, I suppose, clearly understood that the said proprietors give up all claim to further alteration of the bridge, from its present state, on account of the head of water directed by the act of parliament to be maintained.

I am, my lord, and gentlemen,

your most obedient,

and most humble servant,

J. SMEATON.

London, 23d June, 1767.

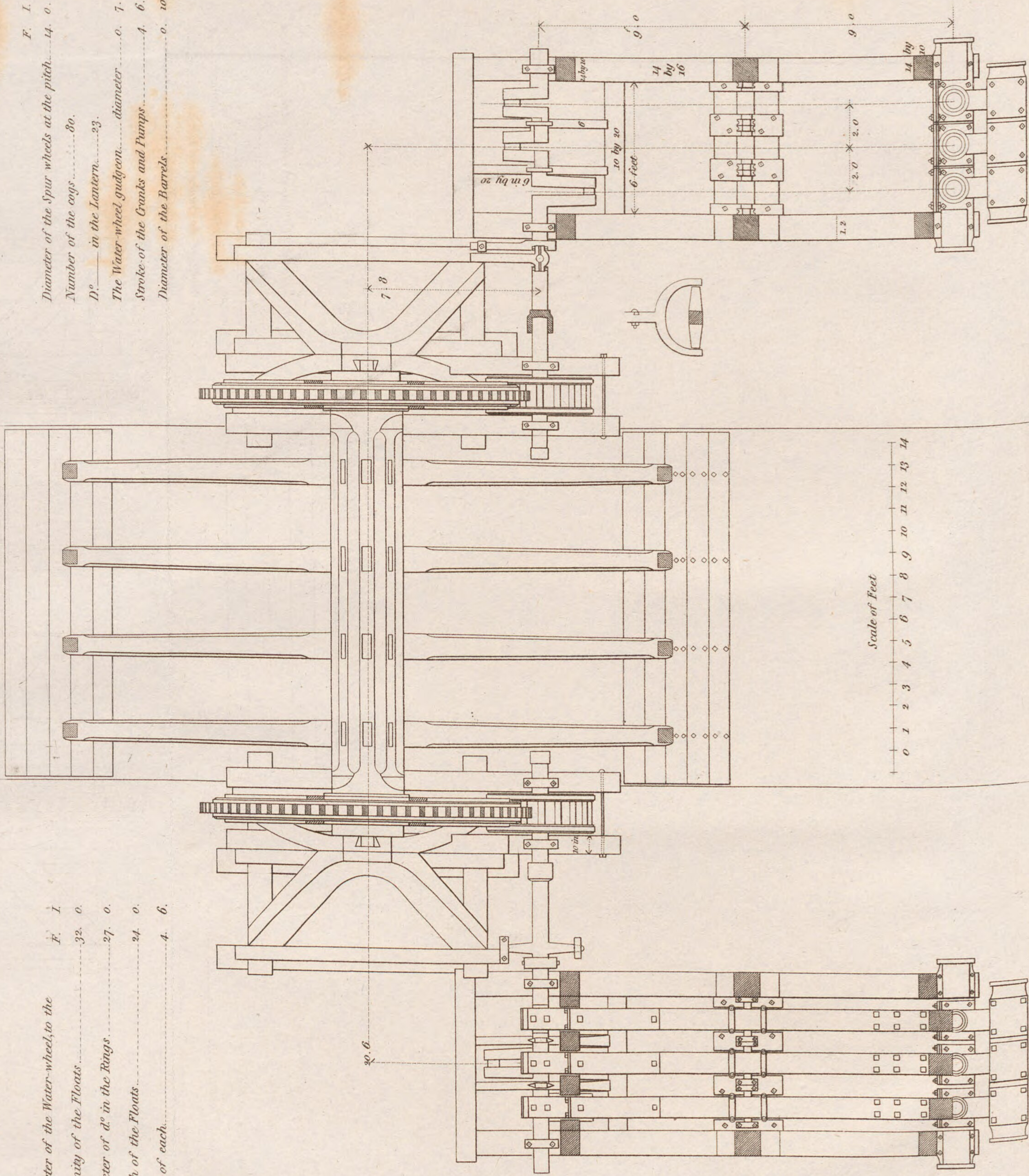
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PLAN of the GREAT ENGINE, for the FIFTH ARCH of LONDON BRIDGE.

Vol. II. Plate III. page 27.

F. I.
 Diameter of the Spur wheels at the pitch..... 14. 0.
 Number of the cogs..... 80.
 D.^o in the Lantern..... 23.
 The Water-wheel gudgeon..... diameter..... 0. 7.
 Stroke of the Cranks and Pumps..... 4. 6.
 Diameter of the Barrels..... 0. 10.

F. I.
 Diameter of the Water-wheel, to the
 extremity of the Floats..... 32. 0.
 Diameter of d.^o in the Rings..... 27. 0.
 Length of the Floats..... 24. 0.
 Width of each..... 4. 6.



Designed by J. Smeaton 1768.

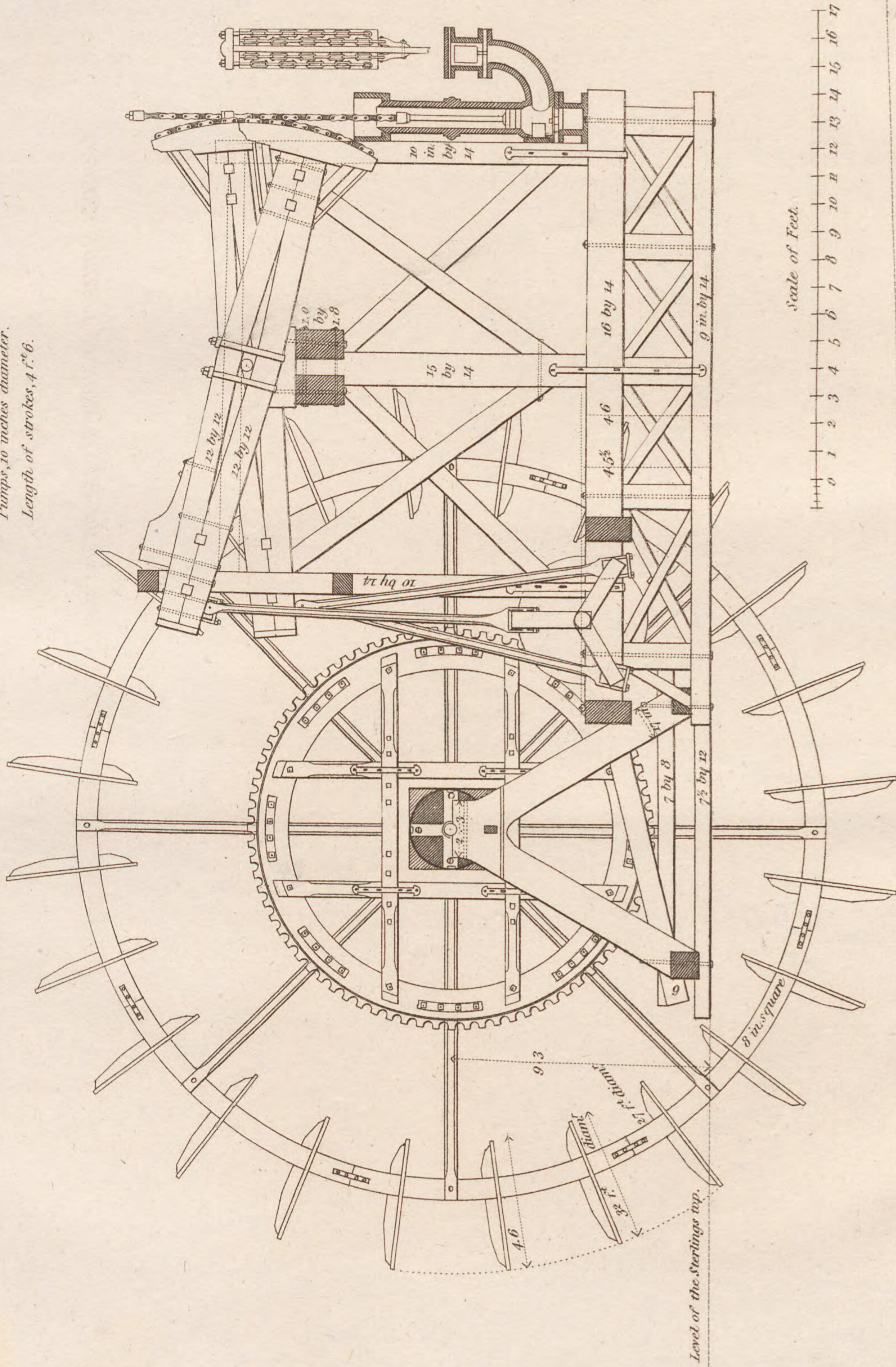
London Published by Longman Hurst Rees & Orme 1810.

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ELEVATION of the GREAT ENGINE, for the FIFTH ARCH of LONDON BRIDGE.

Vol. II. Plate II. page 27.

Spur Wheel, 80 cogs.
Lantern, 23 d.
Pumps, 10 inches diameter.
Length of strokes, 4 f. 6.



Designed by J. Smeaton, 1768.

London. Published by Longman, Hurst, Rees & Orme, 1810.

J. Farley delin.

Lowry sculp.

INSTRUCTIONS for Mr. NICHOLLS to proceed with the water-wheel and spur-wheels for the great engine, to be erected under the fifth arch of London Bridge.

	Feet.	Inches.
1st. The diameter of the water-wheel, to the extremity of the floats,	32	0
2d. The diameter of ditto in the rings, out and out,	27	0
3d. The width of the wheel, or length of the floats, to be as great as a sufficient clearance of the lock will allow ; I suppose	15	6
4th. The number of the floats to be twenty-four,		
5th. The width of each to be	4	6
6th. The diameter of the spur-wheels to be, in the pitch circle,	14	0
7th. The number of cogs eighty,		
8th. The number of ditto in the lanthorns, twenty-three,		
9th. The water-wheel gudgeons to be in diameter,	0	7
10th. Length of the cylinder part,	0	7

REMARKS.

I suppose the water-wheel to stand as near the arch as possible, to leave a sufficient clearance, and to go as near the bottom as possible to be safe.

2dly, I propose the tails of the starts to reach through the rings, so as to support the inside floats, and to make up the whole breadth four feet six inches ; the rings to be clasped by the boards, half-way from one side, and half-way from the other.

3d. I suppose that four rings will be sufficient, at four feet distance, middle and middle ; more rings than necessary, on account of strength, being prejudicial.

4th. I suppose the gudgeons to be fixed on crosses, seven inches in breadth on the face, and $7\frac{5}{8}$ breadth on the inside, and to be $3\frac{1}{2}$ inches thick. One hoop at each end will be sufficient, and should be five inches broad, and at least $\frac{3}{4}$, (but better of one inch), thick ; it should have eight holes for strong short spikes or dowells, two in each quarter, and about $1\frac{1}{2}$ or two inches from the inside ; the hoops should be adapted to the crosses, but to bring all home tight, a groove in each end should be left for iron wedges, as described in the elevation plate II. As the intersection of the cross will form a base larger

larger than the gudgeon, this is to be filled up by a fillet of about $\frac{1}{2}$ an inch projection, according to the length of the axis, which will not only strengthen the joining of the gudgeon to the cross, but make a regular shoulder, which will keep the end of the axis clear of the head stock. The different breadths between the faces and back of the arms of the cross forming a dovetail, will, when wedged in, be alone sufficient to keep them fast, but not depending altogether on the wood, four screws, of about one inch diameter, are put in about four inches within the ends of the cross, as described in the elevation plate 2. which fasten with four nuts, let sideways into the distance of about eight inches behind the inside of the hoops, which done, the holes are plugged up again in the manner of bed screws. The heads may be cylinders of about two inches diameter, and one inch in length, to be sunk with a square shoulder, flush with the arms. N. B. The hoops must be as large as the wood will allow.

5th. I suppose the construction of the arms, rings, starts, and floats, to be according to the method of fixing which has been found, by experience, to answer best, as also the spur-wheels are proposed much larger than what has been used before; that in case compass arms cannot easily be procured, in order more equally to support the circumference, the square formed by the clasp-arms may be one foot on a side, if necessary, larger than the axis, which, being filled with blocks, and wedged, may be fixed as tight as if the axis were of that size.

J. SMEATON.

Newcastle, 17th July, 1767.

To the Committee of London Bridge Water-Works.

GENTLEMEN,

HAVING carefully examined and considered the construction of your fire engine, I am of opinion as follows: That as in the present situation of the pipe for supplying the well, the engine cannot have a proper quantity of water at low water, I entirely approve the proposition of laying an horizontal suction pipe, in order that the engine may take the water immediately out of the Thames.

This will, however, lay some additional burthen upon the engine, but as at present it works by a secondary power, that is, the power of the atmosphere lifts a weight, which weight, in descending, raises the column of water; the addition of burthen would be more than compensated, were the engine made to raise its column immediately by the power of the atmosphere.

To produce this effect, it will be necessary to change the working barrel, with the valves and machinery dependent thereon; and at the same time that the working piece is changed, a new one may be introduced, whose proportion will be more advantageous.

At present, the whole of the water raised by the fire engine is raised to the top of the tower, 120 feet high, as I am informed, though it most commonly happens that one half, two thirds, or three-fourths of that height, would be sufficient. I would, therefore, propose it as a very material improvement, not only to save fuel, but to raise more water, to unite the main from the fire engine with those from the water engines, by which means the fire engines will, like the water engines, never be burthened with a greater column than is sufficient for the service then on: to this I am sensible there is an objection, viz. that the column to be lifted by the fire engine being then variable, the fire engine will not work with the requisite degree of steadiness, which would certainly be the case in the ordinary way of applying the injection, but as I have found out and experienced a method of applying the injection, whereby the engine-keeper is enabled, extempore, while the engine is working, to vary the quantity proportionable to the column to be lifted; hereby the ill effects arising from a variation of the column will be altogether prevented, and a proportionable saving will be made in the fuel.

As

As the engine at present, when lifting the whole column to the top of the tower, would bear a greater load, and would consequently be considerably under loaded when the column was lowered as above proposed, instead of a twelve inch, as now, I would propose to put in a thirteen inch working barrel, by which means the engine will every stroke raise one fifth more water, and by virtue of the changes above mentioned, I expect the coals will be reduced from three bushels per hour, as at present, to two at an average.

Some other smaller alterations may also be made with benefit: and the whole machine wants a repair, particularly the arch heads and chains, and the beam will want to be strengthened.

The boiler is too small for the cylinder, and not of the very best proportion; but as I understand it is in good condition, and may serve some years, I do not at present recommend any alteration in that part.

J. SMEATON.

London, March 8, 1771.

P. S. I do not mean that the engine will lift the water to the top of the tower with two bushels of coals an hour; but I expect it will (besides the additional load of friction) work a thirteen inch working barrel in lieu of a twelve, and without any additional quantity of coals, in consequence of altering its mode of lifting.

J. S.

11th March.

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Fig. 1.

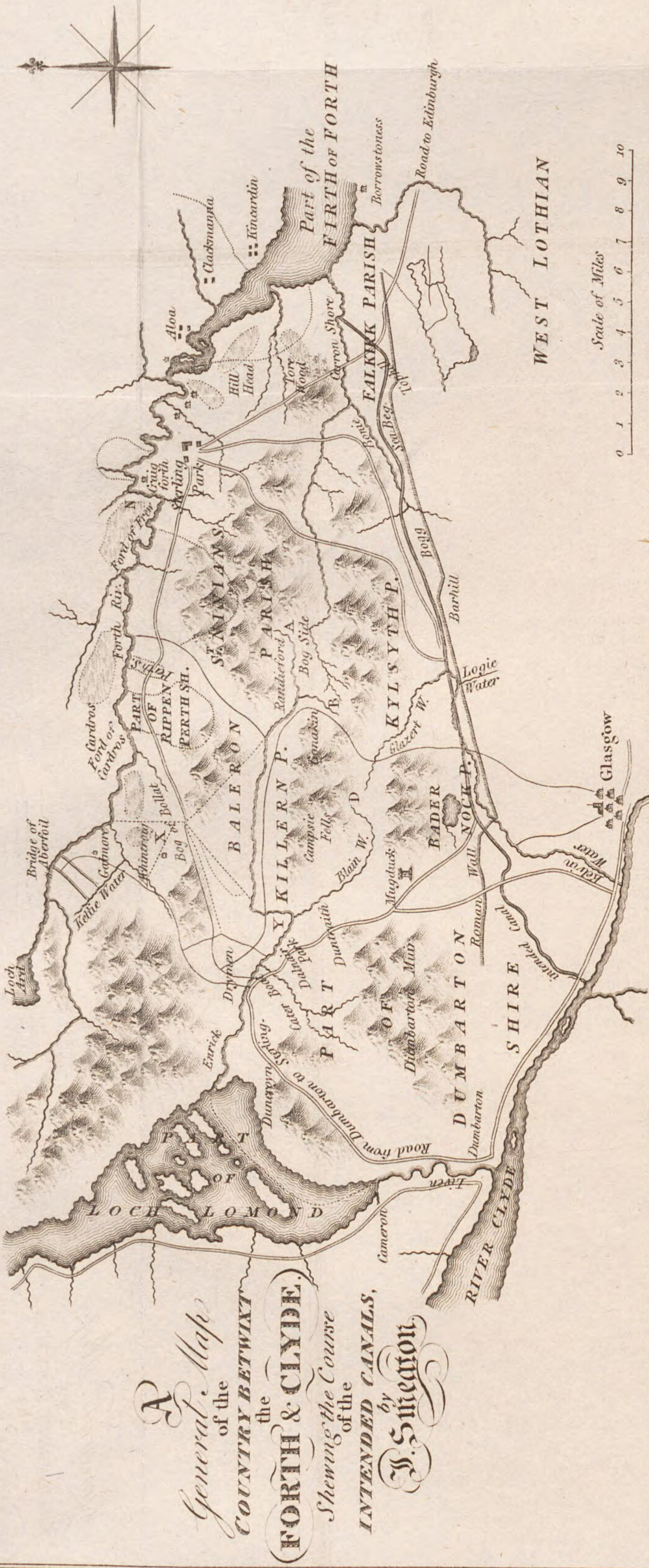
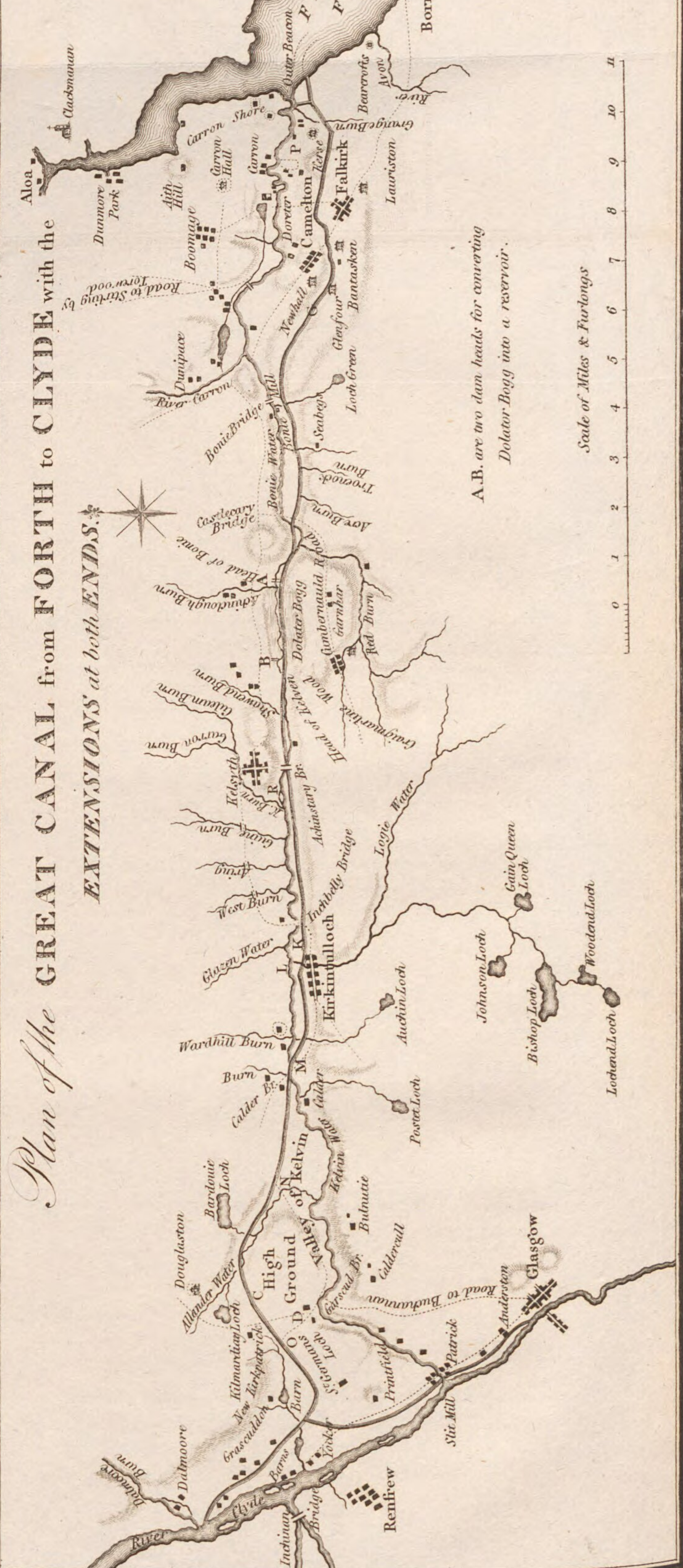


Fig. 2.



The FORTH and CLYDE NAVIGATION.

To the Honourable the Trustees for improving Fisheries and Manufactures
in Scotland.

The REPORT of JOHN SMEATON, Engineer and F. R. S. concerning
the practicability and expense of joining the rivers Forth and Clyde, by a
navigable canal, and thereby to join the east sea and the west.

THE great utility of a navigable communication between the east sea and the west, has given occasion to several projects for this purpose, in different parts of the kingdom of Great Britain. The principal of which are the Thames and Severn, the Trent and Severn, the Trent and Weaver, the Calder and Mersey, and the Forth and Clyde. But from what I have seen and heard of these matters, I am well convinced, that by far and most easy to be accomplished, not only in point of distance, but in point of perpendicular height, is the last, and it is somewhat remarkable, that notwithstanding the country at this place lies in general as high, if not higher, than any of the rest; yet, that through this high ground, there happen to be two different passages, both lower than any of the others, and so much appearance of equality in point of practicability, that upon ocular surveys, it has remained a doubt which of the two ought to be preferred.

One of these passages is from the river Carron, by way of the water of Bonnie, through the bog of Dolater into the Kelvin, and from thence into the Clyde by way of the Yocker Burn. See the plan, pl. IV. fig. 2.

The other is by following the river Forth some miles above Stirling, and then crossing over through the bog of Bollat into the water of Enrick, down to Loch Lomond, and from thence by the river Leven into the Clyde, at Dumbarton (see the map, plate IV. fig. 1.), and as I have, by order of the honorable the trustees for improving fisheries and manufactures in Scotland, been at some pains in taking proper observations in order to determine the preference of the two passages, I shall first endeavour to settle this question, and then proceed more minutely to explain the several leading points that occur for laying out the design for the preferable tract.

GENERAL

GENERAL DESCRIPTION of the CARRON PASSAGE.

See the plan, fig. 2. and the black line, fig. 1.

From the Forth to about three miles up the river Carron, to a place called Carron Shore, there is at present a good navigation for sea-vessels, drawing from nine to ten feet water, at spring tides, and from seven to eight at neap tides, which, from the cuts proposed to be made across the Loops, as I am informed, is likely to be improved; and so far I consider the present sea-navigation to extend.

From Carron Shore to Top-hill, a little below Camelton Bridge, the ground is gently rising, and adapted as well as possible for a canal. From thence to the point above Camelton, between Newhall and Glenfour, the ground rises near sixty feet in half a mile, and is more uneven, but yet attended with no considerable difficulty; from thence the canal may be managed upon the decline of the high ground so as to run upon a dead level to Castle Cary Bridge, being about four English miles; this tract of ground is intersected with haughs and burns, which occur very frequently, and will therefore require a considerable expense in making banks, aqueducts, and other extra works, yet nothing occurs but what may be conquered at a reasonable charge. The principal single work will be an aqueduct bridge in crossing Bonnie mill Burn, near Bonnie Bridge, over which the canal must be carried upon arches. Another, but less work, of the same kind, will be required in crossing the river Bonnie, at Castle Cary Bridge. From hence to the bog of Dolater, which begins a little above Wineford; the passage is sufficiently easy by a gentle ascent, and through the said bog, (extending almost to Craigmarline wood), there is scarcely four feet descent either way, in the compass of two miles; about the middle of which is the summit between the two seas, and is elevated above high water neap tides, at Carron Shore, about 147 feet, being distant therefrom about nine English miles. On each side of Dolater bog the country rises high, which affords a number of springs and rills, which brings down considerable quantities of water on the least rain; but the principal, which is constant all the year, is the burn of Achinclough, which discharges itself into the bog, and which, though it now runs into the waters of Bonnie, might, with very little trouble, be turned, so as to run the other way into the Kelvin; for a drain that now passes lengthways through the bog, has, for half a mile in the middle thereof, no sensible run at all; so that the same trench is the head both of the Bonnie and Kelvin. This bog, as it is called, is properly a peat moss or morass, and is in general near half a mile broad, but contracted

at each end by the high land at A and B, to about 120 yards; so that it is adapted as well as possible for the formation of reservoirs, canals, and passages for water: indeed the whole bog might easily be put under water, by a small dam between the high grounds at each of the contracted places. From the summit, or point of partition, westward, the Kelvin runs in an open valley for about thirteen miles, upon a very regular and almost insensible decline as far as Gariscud Bridge, where it begins to be more rapid, and runs through a very deep channel, quite confined by rocks and precipices, in some places almost perpendicular, and down to Partick, where it falls into Clyde. Of this district, all that can be said, is, that it is not impossible to be made navigable, but it would cost a great sum to make a bad navigation; for this reason, those who have turned their thoughts towards this project, have sought out for a new passage into Clyde; and Nature has kindly furnished two that are practicable, one by the valley of the Allander, leaving Douglastoun, Kilmardoney, and new Kirkpatrick, all on the right, and cutting through a rising ground between the two last places at C, we are conducted into a valley leading down to Grascaddon. The other passage leads out of the Kelvin's valley, just above Gariscud Bridge, and going by way of Canny's Burn, traverses a rising ground at D, and falls into St. German's Loch, and from thence, by the same valley as the former, to Grascuddon. Neither of these passages is without difficulty, on account of the rising ground to be cut through, being above thirty feet perpendicular above the general level, yet both are greatly preferable to the passage by the Kelvin, below Gariscud Bridge, which, besides the incumbrances already mentioned, is filled with mills of various kinds, which occupy the ground where any cut could easily be made. At Grascuddon the ground falls considerably in a little space, and then the passage is very easy and regular down to Yocker Burn, which discharges itself into the Clyde, almost opposite Renfield, and a little above a place called Barns of Clyde; from hence downward the Clyde is navigable at all tides with any vessels that can be expected to navigate upon the intended canal, which I would propose to be such as could occasionally go from Port Glasgow or Greenock, to Leith. From the point of partition of the waters, in Dolater bog, to Barns of Clyde, by the course of the canal, will measure about eighteen English miles (to which measure I all along confine myself), so that the whole length will be about twenty-seven English miles.

GENERAL DESCRIPTION of the Passage, by way of Loch Lomond.

See the Map, pl. IV. fig. 1.

BEGINNING from Clyde to Dumbarton Castle, we enter into the river Leven, which, though but $6\frac{1}{4}$ miles long, measuring by the links or turnings thereof, is yet a large river, and brings down a considerable quantity of fresh water at all times of the year; for having the great lake, called Loch Lomond, for a reservoir at its head, which receives the water of several considerable rivers, it always affords a considerable currency in the dryest seasons, and is never subject to any great or sudden floods on account of the great capacity of the aforesaid lake. This river is, in a state of nature, navigable for flat-bottomed vessels from the Clyde to Loch Lomond, in winter, and wet seasons in summer; but, in dry seasons, the navigation is in a manner stopt; for though it affords a good deal of fresh water at all times, yet as it is broad, and runs in a shallow channel (except about a mile above Dumbarton,) and has about twenty feet fall from Loch Lomond to high water at neap tides, which are sensible at a place called Dalquurn Bleachfield, about a mile and a half above Dumbarton, consequently there is twenty feet fall in less than five miles, which makes the water somewhat rapid, and, in dry seasons, leaves not above eighteen inches in depth over the shoals, which are pretty numerous; and though it might not be difficult to improve this navigation, so as better to answer its present purposes, yet it is not capable of any remedy adequate to the purpose of a general navigation, otherways than by locks and dams, to pen up the water from one to another; for as the river checks in with the high ground, first on one side, then on the other, the valley is but ill adapted to a canal the whole length.

From the head of Leven, we traverse about seven miles of Loch Lomond, in which there is no impediment till we come near the mouth of the river Enrick, which having its source in a high country, comes down very rapidly, and brings a great quantity of sand from the mountains, which is lodged near its mouth in the lock, and there, as it were, forms a bar; over which, in the summer state of the loch, there is not above eighteen inches water, while it serves as a ford in most seasons. To attempt making a passage through this sand, by lifting the matter, would be endless; for, being situated in a bay which lies open to the west wind, the sand is brought back upon the shore by the action of the wind and waves. I have since been informed that at the south corner of this bay, near a place called Aber, the shore is clear of sand; but being there rocky, to make a passage through the same, of sufficient depth below the surface of the loch

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in its lowest state, for the passage of loaded vessels, would probably be more expensive than the removal of the bar itself, which, I apprehend, might be done by running out two jetties about $\frac{3}{4}$ of a mile into the loch, (for, according to my information, 'tis that distance from shore, in dry seasons, before we should find any navigable water), in which case the current of the river, being confined between the jetties, would scour out the sand, and keep the passage clear.

From the mouth of Enrick, the river runs in an open valley, in a deep channel, and almost upon a dead level, as far as Cater Boat, opposite Drummond; which, in a right line, is about $3\frac{1}{2}$ miles, but by the course of the river, which is very winding, cannot be less than six. From hence to the south-west corner of Dalnair Park, the river measures $2\frac{1}{2}$ miles; the perpendicular rise is almost eleven feet. The valley so far continues open, but as the channel is very winding, and checks in with the high ground on both sides, several times, the best way of making it navigable will be by locks and dams, as the Leven.

A little above this, that is, a little above where the water of Blain falls into Enrick, the valley is quite contracted, and the river falls over a set of rocks, forming a remarkable cataract, called the Pot of Gartness, marked Y, to pass which, in the channel of the river, would be very difficult, but this may be avoided by cutting across the neck of land from the south-west corner of Dalnair Park into the river above Gartness Mill, the length will be about a quarter of a mile, and the perpendicular rise about thirty-seven feet. In this passage we meet a hill, whose summit rises above forty feet higher than the level of the river, at the aforesaid cataract; but as the length of the hill is not great, it may be pierced with equal ease, and by the same means as those mentioned in crossing from the Kelvin to Grascuddon, in the other passage. This passage, by the way of Enrick, in the general map, fig. 1. is shewn by a line of strong dots.

Having regained the river Enrick, above Gartness, there seems no way but to follow the course thereof, $1\frac{3}{4}$ mile, in which space there is a rise of twenty-five feet. This passage is sufficiently rugged, and the valley confined by steep brays and rocks; nor do I see any adequate means of avoiding it, as the country hereabout is very steep and uneven; however, it may be managed by locks and dams, upon the same principle as those below. From hence, it is proposed to pass by canal to the bog of Bollat, the summit of which is distant a little more than a mile, and is elevated above the aforesaid point in the river, 129 feet, viz. from the river's surface to the top of the
 bray

bray thirty-five feet, and from thence to the summit of the bog 94 feet; so that the summit of the bog of Bollat is elevated above the surface of Loch Lomond 202 feet: and above high water neap tides in the Clyde 222 feet, the whole distance being twenty-five miles.

The bog of Bollat is about half a mile long, and about one-eighth of a mile in breadth; from the middle or summit, the ground falls away pretty quick both ways, and the valley widens: no constant running waters discharge themselves into this bog, except one small rill that comes in on the north side; there is, however, a burn, called the Auld Hurr, marked X, which falls into the decline of the valley towards the Forth, which might easily be conducted to the summit; but this, at the time I saw it, after a remarkably rainy season, was far short of supplying a navigation. There is also another burn to the west of Bollat, affording much about the same quantity, which falls into Enrick, the upper part of which might be intercepted and carried to the summit, but still there would remain a great deficiency. I should not, however, despair, did the point of difficulty rest here, of bringing a sufficiency of water to the bog of Bollat, and making proper reservoirs there; for it appears, from the face of the country, practicable to lift the water of Enrick, four or five miles above, so as to bring any quantity required to the point of partition, or even to bring a part of the Keltie water upon a sufficient elevation round the hills to the same place.

From the point of partition in the bog of Bollat, a valley gradually forms itself to the north, into which the waters from the neighbouring hills collect themselves, and form a burn; which, passing by Achintroig, and a place called Offrings, falls into the river Forth, a little below the mouth of the Keltie. From the summit of Bollat to the river Forth is above four miles, the last mile of which being through the valley of the Forth, has but little descent, so that the greatest part of the whole descent is in the three former miles.

From the mouth of Keltie to Stirling, the river Forth runs in a remarkably winding and deep channel, and with a slow current; which is, however, interrupted at three principal places, viz. at the foot of Cardross, where there is a fall of about two feet; at the ford of Frew, where there is the like fall, and at Craigforth mill, at N. about $1\frac{1}{4}$ mile above Stirling, where there is a fall of four feet.

The falls at Cardross and Frew are occasioned by gravel shoals formed there in the river, and brought down from the hills by the burns that fall into the Forth, near those places;

places; but that at Craigforth mill, N. is occasioned by a natural rock, which runs across the river, the defects of which, as a dam, is made good by art, in order to produce a sufficient pen of the water, to work the mills, and to catch salmon. The spring tides come up to Craigforth mill, and the river is then navigable for lighters or barges to this place, and, according to my information, at neap tides, within half a mile below this place.

Above Craigforth mill, a navigation is at present carried on upon the Forth in small boats as high up as Gartmore, except in very dry seasons; these boats bring down lime-stone from the rocks near that place, as I was told. Two locks and one dam would make an open navigation from Gartmore to the Firth of Forth, at all seasons of the year; and were there any trade of consequence up this extensive valley, would be worth the while, independent of a navigable communication between the two seas. One lock ought to be placed opposite Craigforth mill, and the other lock and dam at the ford of Frew; this, with a little clearance of the shoal at Cardross, would make a navigable passage over the same.

From the mouth of the Keltie to Stirling, is about twelve miles, in a straight line, but by the course of the river, appears to be more than twenty. It may seem that this might be helped, by cutting through some of the most remarkable loops, but the surface of the river lies so much within soil, that these cuts, though short, would be required to be so deep, that the advantage gained would be by no means adequate to the expense, nor would the making an entire new canal be so easy a matter as the seeming flatness of the valley would indicate, for, being interspersed with mosses and broad flades, where the burns come down, which are numerous, the surface of the moss is elevated several feet above, and the flades depressed as many below the mean surface; so that what with extra cutting in some places, and extra banking in others, together with the works necessary in crossing the burns to get rid of their waters in rainy seasons, this work would be made very expensive.

From Stirling to Alloa, there is at present an open navigation, but through so winding a passage as is almost without a parallel, it being accounted four miles by land, and twenty-four by water: some of these loops, I apprehend, it would be worth while to cut, for the improvement of the navigation.

According to this description, it measures by the course of the rivers, &c. from the summit of the bog of Bollat to Alloa, at least forty-eight miles, and from Dumbarton
to

to the summit of the bog twenty-five miles, so that the whole course, from Dumbarton to Alloa, by the loops of the rivers, will be seventy-three miles; and it further appears, that by the most direct passage that can be made, it will be at least forty miles.

COMPARISON OF THE TWO PASSAGES.

FROM what has been already observed, it is manifest that the Loch Lomond passage is considerably further about than the Carron passage, and that it is at least equally embarrassed with difficulties; the only point, therefore, in which a competition can be supposed, must be on account of expense. In order to bring this matter into a narrow compass, I will suppose the Loch Lomond passage to be done at the least possible expense, in which case the distance, as before mentioned, will be seventy-three miles. The impediments being supposed equal, the difference of expense will lie in two articles, *viz.* the difference of length of the artificial part of the navigation, and the difference of the lockage. To reduce the difference of expense arising from the difference of length of the artificial part, to the most simple form, I will suppose in favor of the Loch Lomond passage, that the parts of the river to be made navigable, by means of dams, &c. to be the same expense as the same length of canal, though in general, this kind of work turns out more expensive in such embarrassed situations.

	Miles.
The length of the river Leven, in a right line,	4
The river Enrick from Loch Lomond, to the S. W. corner of Dalnair Park, in a right line,	5
From hence to the point of departure from the Enrick,	2
From thence by canal to the summit of the bog of Bollat,	1
From the summit of the bog of Bollat to the nearest part of the river Forth, near Offrings,	12
The cuts and dams upon the Forth being reckoned at one mile, will be greatly undervalued,	4
Total length of the artificial part in the Loch Lomond passage,	17
The Carron passage, measures	27
Difference of length of artificial navigation, in favor of Loch Lomond,	10

According to this description, it measures by the course of the rivers, &c. from the summit of the bog of Bollat to Alloa, at least forty-eight miles, and from Dumbarton

	Feet	Inches
The perpendicular height of the summit of the bog of Bollat, above the neap tide high water surface of the Clyde, at Dumbarton, - - -	222	0
The height of the summit of Dolater bog, above high water neap tides, at Carron shore, -	147	0
Difference of perpendicular height, in favor of Carron shore, - - -	75	
But this difference of perpendicular height in point of lockage will be double, - - -	150	
	£.	
I estimate the cutting at £1250 per mile, extra banking, bridges, tunnels, towing-paths, and contingent works, therefore ten miles will come to - - -	12,500	
The lockage I estimate at £133 per foot, rise or fall, the difference being 150 feet, comes to -	15,000	
The difference of expense in favor of Carron, - - -	£2,500	

So that the Loch Lomond passage will cost £2500 more than the Carron passage, is further about by almost forty miles, and will be attended with an additional loss of time in passing, and expense in keeping between thirty and forty locks in repair.

I presume I have now said enough on this head.

FURTHER PARTICULARS relating to the Carron Passage.

HAVING already given a general description of the path by which the canal may be conducted from Carron shore to Barns of Clyde, it remains that I now enlarge upon some matters relative to this scheme, not yet sufficiently explained.

First, As to the method of supplying the canal with water. The first and grand principle is to bring a sufficiency of water to the point of partition, which is here in the middle of Dolater bog, between A and B fig. 2. not only to answer the expense of water in filling the locks on the passage of vessels, and of the constant leakage that will always be, more or less, through the gates thereof, but also to make good any waste that may happen by soakage through the banks, and into the ground where the canal is carried, above soil, or upon an elevated part of the country, or that may arise from the exhalations from the surface, by the sun and winds in dry seasons; and it is very evident that the supplies for all these purposes must depend upon the water brought to the point of partition till other supplies can be brought into the canal at a lower level in aid thereof. Now, the space of canal that I look upon will chiefly depend upon the point of partition for its supply, will be from the falling in of Redburn, a little above Castle Cary Bridge, east, to Inch Belly Bridge, upon the Kelvin,

vin, west, which includes a space of $7\frac{1}{2}$ miles ; but before we can determine the quantity of water necessary to supply this space, we must first determine the kind of vessels proposed to navigate this canal, and the tonnage of goods that may be supposed to be carried thereon.

With this view I examined the ga boats, which ply upon the Clyde, and are capable of navigating that Firth in all common seasons, and which I apprehend by the same rule would navigate the Firth of Forth, between the canal and the port of Leith, if found requisite so to do. I found that a middling ga boat of fifty-six feet long, stem and stern, seventeen and a half feet wide, and drawing four feet water, will carry at least forty ton, and this I look upon to be the largest size that will be convenient for an artificial navigation. Now, suppose twenty of these boats pass per day, at an average, in the dryest seasons, that is, ten each way, and supposing them to go full loaded from the Clyde to the Forth, and half loaded from the Forth to the Clyde, they will carry 600 tons of goods per day, and 4200 tons per week ; in which I reckon seven days : for though the boats should not work on Sundays, yet, as the water will be amassing, the capacity of carriage, in point of water, will not be diminished, which will also be the case, though they do not go regularly. But casting off the 200 tons for accidents and disappointments, and reckoning upon 4000 tons per week, this will amount to 208,000 tons per year, exclusive of what may be further done, when the supply of water is unlimited. The lock duty, exclusive of freight, would, I apprehend, very well bear five shillings per ton ; but at two shillings and six-pence, 208,000 tons, would amount to £26,000 per annum ; from hence I would infer, that if we could furnish water in dry seasons for twenty boats per day, there will be water enough at the lowest tonnage that can be supposed, to raise a much greater annual sum than can be wanted for repairs, and to discharge the interest of the capital to be expended thereon, and in all probability, more water than the trade can possibly want ; but I would not have it inferred from hence, that because the canal can carry 208,000 tons per year, that there will be 208,000 tons per year to carry ; consequently, the price of tonnage must be fixed upon the probability of carriage, which I leave to the decision of those who are better skilled than I am both in the general trade of this kingdom, and the particular trade of those parts.

Now it is certain that every vessel in its passage cannot require more than two locks-full of water, out of the canal of partition ; one at its entry, the other at its departure, which locks-full of water, will either furnish the same vessel, or some other, with a passage through all the rest ; supposing them of no greater perpendicular rise : I say, cannot

cannot require *more*; because, if two vessels meet at a lock, one going down, the other up, they may both pass with one lock-full; but supposing the worst, that is, that every vessel take two locks-full from the canal of partition, the size of the vessels being as before mentioned, will require the locks to be sixty-four feet long, and eighteen feet wide; and supposing the rise at each lock to be three feet from the canal of partition, to Redburn one way, and to Inch Belly Bridge the other, the water necessary for the passage of a vessel will be 3,456 cube feet at each lock, at the extremities of the canal of partition, at A and B, and at both 6912, and for twenty boats 138,290 cube feet per day.—A well made lock will not leak above its own capacity in twenty-four hours, but as things cannot always be equally in order, we will allow two locks-full per day leakage, and as they may be misused by the carelessness common to watermen, we will allow two more on this account, amounting to 13,824 cube feet, which, added to the lockage, 138,240 cube feet, makes 152,064 cube feet of water, to be expended in twenty-four hours. Now, within the limits before-mentioned, this will be the whole; for, in regard to soakage, as the canal will be carried in the sink of the valley, and dug out of the solid, it will not be above the common drainage of the country, and therefore will be more likely to acquire water by cutting of springs than to lose by soakage. In regard to exhalations, I have observed in respect to ponds, canals, and other stagnant waters of a competent depth, that had no springs, but yet were water tight, that in the greatest extreme of the late dry summer, the loss never amounted to above ten inches in their perpendicular height before they were replenished by casual rains: now I propose that every part of the canal should be dug one foot deeper than the draft of the water of the boats, by which means the boats will have sufficient freedom to their motion; and the canal will contain within itself a reservoir or magazine for supplying the exhalations.

The next point is, to enquire how this quantity of 152,064 cube feet of water is in dry seasons to be collected, and brought to the summit of Dolater bog every twenty-four hours; and the first thing that presents itself is the burn of Achinlough, which discharges itself into the bog as already mentioned.—This burn, according to information I received from the miller at Achinlough, is capable of furnishing water in the driest seasons sufficient to work his mill $4\frac{1}{2}$ hours per diem; now, from the quantity I found necessary to work the mill, this will amount to 89,343 cube feet per diem.

The burn of Kylfith, by the same kind of examination, at Kylfith mill, I find will deliver 87,003 cube feet in the same time; the sum is 176,346 cube feet that these two burns will furnish in twenty-four hours in the driest seasons; that is, more

by 24,281 cube feet, than as before required, which affords a surpluſage of ſeven locks-full per diem, to answer contingencies, beſides ſome other ſupplies that ſhall be mentioned.

The burn of Kylaith falls into the Kelvin a little below Achinvole, marked R. at a place about twenty feet below the ſummit of the bog, but as this burn comes down from the high ground, it can be intercepted and carried to the point of partition. The moſt eaſy and convenient way of doing this, will be to take it up at the tail of Kylaith mill, and carrying it eaſtward upon the declining ground, it will croſs the ridge of hills to the north-eaſtward of a place called Craigſtones, and fall into the Shawend burn; with which it can eaſily be carried to the place of deſtination: from an obſervation not very minute, it appears to me, that there is a ſufficiency of elevation to carry Kylaith burn over into Shawend burn, from the tail of the mill; but ſhould there, upon a more accurate level, prove ſcarcely enough, yet the purpoſes hereby intended would not be defeated, as there is a fall of between thirty and forty feet juſt above the mill, ſo that by raiſing the mill wheel, an additional fall of twenty feet might be gained from the tail thereof, without detriment to the mill.—Shawend burn is ſaid to afford ſome water in the dryeſt ſeaſons, and in common ſeaſons a conſiderable quantity.—At the eaſt end of the bog, at Wineford, a coal-pit drain diſcharges itſelf, which affords a conſtant ſupply of water, amounting to ſome locks-full per day: I have not, however, brought theſe ſupplies to account, becauſe, it appears from the preceding calculation, that the two burns of Achinlough and Kylaith are of themſelves ſufficient: I have taken notice of thoſe others therefore, as a means of ſupplying deficiency, if any ſuch ſhould happen to ariſe from unforeſeen cauſes. Nor are thoſe the only ones that can be ſo applied, becauſe, if it ſhould prove neceſſary, Redburn, which, together with Achinlough, forms the river Bonnie, a little above Caſtle Cary Bridge, may eaſily be brought to the point of partition; for the level of the ſurface of Redburn, at the point of confluence, is not more than twenty-three feet below the ſummit of the bog, and diſtant about a mile, and as Redburn is very rapid, it may be lifted ſo as to run to the point of partition, without going any conſiderable diſtance up the burn. This burn I look upon from inſpection, to be at leaſt as good as either Achinlough or Kylaith burns, ſo that, together with the reſervoirs for water that may be formed both in the bog, and in the hollows of the contiguous hills from whence theſe burns proceed, it does not admit of a doubt but that nature has furniſhed the means of bringing as much water to the point of partition as can poſſibly be wanted; and that by methods ſufficiently ſimple and eaſy.

I have mentioned that the space depending upon the waters to be brought to the point of partition, is that between Redburn, east, and Inch Belly Bridge, west; for at all those places the accession of waters, by taking an occasional supply from Redburn into the canal on one hand, and on the other by taking in the Kelvin at Inch Belly Bridge, will not only contravail any deficiency by leakage or soakage, between their junction with the canal and its termination each way respectively, but also to allow of one foot of greater height in the locks below those points, to avoid too great a multiplicity thereof.—By taking the Kelvin into the canal at Inch Belly Bridge, the whole collection of little rills and springs that fall into the Kelvin below the level of Kylesith mill, (of which there are several constant ones) will be brought to account, and the communication with the river Loggie, in crossing the same at Kirkintilloch, will be an absolute security against any defect in that branch below the same; so that there is all possible certainty that the canal will be amply supplied from end to end.

Secondly. Having now supplied the canal with water, it remains with me to show how this is to be done without injury to the mills and other works upon the rivers Carron and Kelvin; which, below the mouth of the Bonnie on the Carron, and below Gariscud Bridge on the Kelvin, are not only valuable, but said to be in want of water in dry seasons.

In order to put this matter in a clear light, let us examine for how much water we have, by the preceding scheme, taken credit of the aforesaid rivers; and it will appear that we have taken the burns of Achinlough and Kylesith, with so much from the others as shall be wanting to make up the deficiencies of the former, in supplying the lower parts of the canal with water.

For supplying the locks of three feet rise between Redburn and Inch Belly Bridge, we shall	Cubic feet
want as much as before estimated per day,	138,240
Now, if the locks were proposed to be of three feet all the way, the same water would serve them quite through, but being proposed of four feet below those points, they will require an addition of one-third of the foregoing quantity, which will amount to	46,080
The leakage of the locks were before estimated at	13,824
Total required	198,144
The Achinlough and Kylesith burns supply	176,346
Deficiency to be taken from Redburn, Kelvin, and Loggie	21,798
	which

which deficiency is nearly one-eighth of the whole quantity, supplied by the two burns; that is, as those two burns are said to turn their respective mills, $4\frac{1}{2}$ and four hours, which is together $8\frac{1}{2}$ hours, as much water must be taken from the other rivulets as will turn a common burn mill, with an overshot wheel, a little more than an hour, in order to make good the surplusage above the two burns.

I have not brought the exhalations, and soakage through the banks, into the above account; for, with regard to exhalations, as the whole is proposed to be dug to an extra depth, in order to take in a surplus quantity of water in time of rains (at which times the mills have water enough to spare), this may be laid out of the account: and in regard to soakage, though a supply for that purpose will be wanted from the burns, yet as that will return again into the rivers, it is not lost to the mills; and though some part of the soakage may fall into different valleys, yet as it must be expected, that the rills and springs, which will be intersected by the canal, that used to run into those valleys, will counter-balance the soakage of these parts of the canal, there will still be no water lost to the mills on account of soakage; the quantity then that we are to restore, is the value of the two burns, one equal to Achinlough, and the other to Kylesith, and one eighth part more of each respectively; and this may be done by intercepting and turning some waters that fall into other rivers, into the Carron and Kelvin.

Having, for this purpose, examined the country, I find that a part of the river Enrick, near its source, may be intercepted a little above a place called Randeford, which, being carried to the west of the ruins of St. John the Graham's castle, and passing by a place called Bog Side, through a morass, lies nearly upon a level between the two rivers will fall into the Carron; the place is marked in the general map, fig. 1. with a line A. The waters of Enrick, at the point where it is proposed to be turned, appear to be more than double those of the burn of Achinlough; but if unforeseen occasion should happen to require a further supply, it may be procured by turning the upper part of the burn of Gonakin into Carron, which rises from springs in Campsie Fells, and now falls into Enrick; this is marked with a dotted line B. With respect to Kelvin, the water of Glazert, which falls into Kelvin, and the water of Blain, which falls into Enrick, have their source near the same place, there being a continued flat valley between them, like the Kelvin and Bonnie: near the point of partition of the waters, is a remarkable cascade, or cataract, called the spout of Ballagin, marked D, which, falling from the south side of Campsie Fells, immediately forms a considerable burn, whose general course is into the waters of Blain, but is so critically situated, that in time of floods, a part of its waters is sometimes discharged into the Glazert, and with a
very

very little trouble would be made to do so constantly; this is marked in the general map by D. This burn appears equal to the burn at Kylesith mills, and, therefore, may be substituted in its stead; and the eighth part thereof still wanting may be made good by intercepting a number of springs which issue out of the hills on both sides at a sufficient elevation to be carried over the point of partition into the Glazert, which now falls into the waters of Blain. Those springs may be intercepted on the north side, if occasion should require, almost as far as Duntraith.

To this method of supply it may possibly be objected, that in order to re-pay the mills on Carron and Kelvin, I have robbed those on the Enrick and Blain: but here I must observe, that where there is more work than water, to take away a part thereof, though small, is a proportionable loss; but to take away a small quantity of water, where there is much more water than work, is no loss at all.

Upon the water of Enrick and Blain, there are no mills of any consequence; the most considerable are those at the Pot of Gartness, Y, which, as I am informed, are far from being fully worked, and, if they were, as a considerable part of the fall there is unemployed, their power might be greatly increased, though the quantity of water were a little diminished; and it must be remembered, that the whole quantity wanted hence, is only an equivalent to Achinclough burn, and one-eighth more, which burn turns an overshot mill $4\frac{1}{2}$ hours per day; whereas the river Enrick, at the Pot of Gartness, is a considerable river, and has a fall there, as before observed, of between thirty and forty feet. However, to cut off all altercation respecting mills, the trustees to be appointed for the execution of this scheme may safely engage to give the mills on the Carron and Kelvin as much water in dry seasons as they take away, and to make good all damages that may accrue to the others. I shall now more particularly describe some things, which, though hinted at in the general description of the Carron passage, have not been fully explained.

Thirdly. The size of the canal I propose to be twenty-four feet in the bottom, and the sides to be sloped at a medium, in the proportion of five to three; that is, for every three feet depth to widen five feet on each side, or ten feet on both sides; to be five feet deep of water, and at a medium seven feet deep within soil, so that its mean width at the surface of the water will be forty feet eight inches, and to be made wider in convenient places, and at proper distances, for vessels to pass each other. To make the canal less for boats of $17\frac{1}{2}$ feet wide, drawing four feet water, would make them draw hard, and to make it larger, would induce an unnecessary expense. The locks I would propose not to exceed four feet rise at each, in order to save water in working them, and if made with less rises, would be too troublesome on account of their

their number; only between Redburn and Inch Belly Bridge, as water may there be more scarce, I have proposed them of three feet rise each.

The several hollows that the canal will intersect in its passage from Camelton to Castle Cary Bridge, I have proposed to pass by banking across, so as to raise the water in the same up to the level of the canal: the deepest of these is the first to the west of Camelton, marked G in the plan of the canal, fig. 2. which is about eighteen feet deep in the deepest part, and seventy yards wide at the top, the others are less considerable, except at Bonnie mill, which I have proposed to cross on arches, this will be about thirty feet deep, and seventy yards wide at top, but the arches need not extend above thirty yards, the rest may be done by wharfing and banking. The aqueduct bridge that will be wanted in crossing the river Bonnie just below Castle Cary Bridge, will be necessary, not on account of the depth of the valley, but to give the river a free passage under the canal; four small arches of ten feet each, will here be sufficient; but if it be thought more eligible in the execution, the crossing the river may be effected by forming a dam or weir across the river Bonnie, but this will destroy the fall of Castle Cary mill. From hence to Dolater bog there are no difficulties.

The canal of partition extending about $1\frac{1}{2}$ mile between the two locks at its extremes, marked A and B in the plan, I would propose to be dug out fifty feet wide at bottom, with slopes as before, which will form a reservoir for water, capable of holding three days supply upon a foot in depth: this is as much as can be wanted, especially at first, till the canal has got a large trade upon it, and if any thing further should appear necessary, especially after the Redburn is brought to the point of partition, I would advise it to be done by banking in a part of the bog, by which means it will be formed sufficiently high to yield its contents into the canal of partition by a sluice, as occasion may require; there will be here included a space of twenty Scots acres, which, at four feet deep, will contain a supply of twenty-five days.

From hence to Inch Belly Bridge there is no difficulty. Below this bridge I propose to put a dam at K, in order to force the water at a proper elevation into the canal K L, which is intended to drop into the Loggie above the mill-dam at L; which dam will again force the water into the canal L M, and which, by proper locks, conducts us into the river at Calder Bridge. A little below this bridge, in like manner, I propose a dam or weir M, to throw a proper body of water into the canal M N, by which we are conducted to the Allander, where the two passages divide, by either of which we may pass upon the same level into the valley leading down to Grascuddon, one up the Allander,

the

the other by Canny's burn into St. German's Loch; a little below which, both passages would unite in the same point at O. It remains, therefore, to give a reason, why, of the two passages, I prefer the latter.

For this purpose, having taken a level from the surface of the water of the Kelvin, just below Calder Bridge, to the summit of each high ground, I found them to differ but inconsiderably in their perpendicular height, the summit of the high ground by the Allander passage being thirty-two, and that by the Canny's burn passage being thirty-three feet above the said water: I likewise upon examination found the base of the hill in the Allander passage, to be a mile and a half, or twelve furlongs, that would require an extra depth of cut; six furlongs of which would be above fifteen feet deep: whereas, in the Canny's burn passage, the whole length that would require extra cutting is not above $2\frac{1}{2}$ furlongs; and there is not quite one furlong that would be above fifteen feet deep. If nature had furnished no other passage than that of the Allander, something might be done towards lessening the expense by retrograde locks, but as this would cause hindrance of time, as well as an additional cost in the article of lockage, there appears to me no way by which it can be done either so well, or so cheaply as by the Canny's burn passage.

Where the depth exceeds fifteen feet, which will not be above two hundred yards, I would propose the passage to be by a vault under ground; and though the matter of the hill seems to be a loose gravel, yet I apprehend the means are not very difficult by which it might be perforated. I would begin at an end and open the ground from the top, the same width I intended it at bottom, that is, eighteen feet, like the locks, with an allowance for the thickness of the walls; and cutting down the sides perpendicular, would shore the same from side to side with boards, beams, and braces, of ordinary Scotch fir, these keeping up the matter till the arch is built, the shores that are above the arch may be taken away, and replaced as the work advances, and the cross braces that interfere with the walls of the arch may be walled in, and afterwards cut out when the whole is completed.

From St. German's Loch, I would carry the canal upon the decline of the hill upon such a level, as, with a little extra cutting, to pass the high ground that lies on the south of the mill-dam of Grascuddon; this I propose, in case it should not be agreeable to the lord of Grascuddon to carry the navigation through this dam; which is an ornamental piece of water, with planting and walks round it; otherwise this part of the canal will be more easily done by passing through this piece of water.—From Grascuddon

cuddon mill-dam there is between twenty and thirty feet fall in a little space, but from thence to the Clyde the ground lies upon a gradual descent, in which there is no difficulty.

At entering the Clyde, a jetty, formed of rubble stone, may be necessary to keep clear the tail of the cut.

Fourthly. With respect to the number of locks: this depends upon the perpendicular height of the whole, and the perpendicular rise proposed to each lock.—The perpendicular rise of the whole I make to be 147 feet, from the high water surface at a neap tide at Carron shore, to the summit of Dolater bog. But as I would propose to keep the surface of the canal somewhat below the surface of the land there, we will call the perpendicular ascent 145 feet. In this I cannot pretend to be exact, for the violent squalls of wind and rain that occurred the whole time of the survey, made it exceedingly difficult and troublesome to manage any instrument for this purpose: it is possible I may have erred some feet in the whole perpendicular, but as from the direction in which the wind generally blew, I am inclined to believe that what error there may be, is by exceeding the truth, if it should be found, upon re-examination, to be five feet less than I have made it, (or even double that quantity,) it will make no alteration in the general design, nor produce any other effect than the saving so much in the lockage of that perpendicular; and hence it appears, that an exact knowledge of the perpendicular is not at present necessary to determine the practicability of the scheme.

It may likewise be questioned, whether the perpendicular elevation of Dolater bog be the same above the Firth of Clyde, as it is above the Firth of Forth; and it is possible it may not; but as water undisturbed naturally places itself upon a level, and as the disturbing causes, viz. the wind and tides, frequently act in opposite directions, we may be assured that the mean height of the two seas is not so different as to make any material difference in the scheme proposed. Accounting therefore the perpendicular height both ways 145 feet, we shall have the number of locks as follows:

	No. of locks
From Carron shore to the intended level of the canal above Camelton, I make to be 108 feet, which, at four feet each, requires	27
From thence to Castle Cary Bridge, the canal being upon a level, will require none, but from Castle Cary Bridge to Redburn, there is a rise of sixteen feet, which, at four feet each, will take	4
From Redburn into the canal of partition, being twenty-one feet, at three feet each, will require	7
No. of locks from Carron shore to the point of partition	38
	From

	No. of Locks.
Brought over	38
From the canal of partition to Inch Belly Bridge, I estimate the fall at thirty-six feet, this, at three feet each, will take	12
From thence to the Clyde there will remain 109 feet, which, at four feet each, will take	27
Number of locks in the whole	77

N. B. The above is the greatest number that can be required, for if in the execution it should appear, that the supply of water should turn out more liberal, or a less number of vessels expected to navigate, than I have supposed, then some expense may be saved by making the rises of the locks greater in general; and without preserving a strict equality, by which means they might be made more readily to suit the ground: it must, however, be observed, that the highest lock determines the quantity of water to be used: for were there but one lock of eight feet in the whole collection, this would occasion as great a consumption of water, as if they were all of the same height; unless an extra supply could be brought to this lock, to set against the extra quantity.

Fifthly. Wherever the canal is by banking held up above soil, that is, above the natural surface of the land, it is proposed to cut back drains behind such banks, to receive any leakage that otherwise might hurt the adjacent soil, and to conduct the same to some common water-course; also to lay tunnels under the bottom of the cut to communicate such water-courses across the same as require to be preserved, or whose elevation may not suit to be brought into the canal. Also to make bridges in proper places over the canal, for communication between such properties as shall be severed by the same, and to make gates upon the towing-paths between every fence, and double-gates, if required, for the divisions between different properties, with over falls in proper places for discharging the overplus waters, and whatever else may appear necessary for preserving each person's property as nearly as may be in the same state as before the execution of this project.

Sixthly. It is very difficult, if not impossible, upon one survey, to take in every view of a subject so complicated; I therefore consider what I have reported as shewing the general practicability of the proposed scheme, with one method of executing the same;

but as it is most probable that many improvements may be made whenever it is re-considered for execution, the trustees appointed should be invested with sufficient power for doing whatever might appear necessary.

ESTIMATE of the EXPENSE.

	£
The canal being twenty-four feet mean width in the bottom, and seven feet mean depth, with slopes as five to three, the width at top will be forty-eight feet, and mean width thirty-six feet, will contain twenty-eight cube yards in each yard running, and in a mile 49,280 cube yards of digging, which, at 3d. per yard, come to £616 per mile, and for twenty-seven miles in length, to - - - - -	16,632
To extra digging in the canal of partition, to make it fifty feet bottom, 53,308 yards, at 3d.	667
For extra work in making several passing places, and some additional measure in turning the angles, allow upon the whole the value of one mile, - - - - -	616
The canal being forty-eight feet top, allow the same width for the banks on each side, that is, forty-eight yards in breadth over all, which makes in one mile 84,480 square yards, which is 15½ Scotch acres nearly; and for twenty-seven miles, 418½ acres, which, supposing them to be purchased at a medium at £20 an acre, come to - - - - -	8,370

N. B. The greatest part of the tract is corn ground, but as there is a considerable quantity of pasture and moor grounds of small value, and the banks being possessed by the owners of the respective lands, are generally supposed to be of half value, I suppose the above price, at a medium, may be sufficient, if otherwise, the extra value must be added.

Besides what is immediately occupied by the canal and its banks, land will be wanted for conveniences, trenches, reservoirs, &c. which in the whole may amount to twenty acres,	400
The number of locks being seventy-seven, £400 each, amount to - - - - -	30,800
To extra digging in passing a narrow gripe, between two rising grounds a little to the south-westward of Mungull's house, - - - - -	100
To extra banking across six haughs, or hollows between that place and Bonnie mills, at an average £100 each - - - - -	600
To an aqueduct bridge in passing Bonnie mill burn, and extra banking up the same, with an over-fall for discharging the overplus water of the canal, - - - - -	1000
To extra work in passing Seabeg's wood, Trannock burn, Acre burn, and some other haughs and risings, from thence to Castle Cary Bridge, - - - - -	400
To an aqueduct bridge for passing the river Bonnie near Castle Cary Bridge, and extra banking there, - - - - -	800
	<u>£60,385</u>
	To

	Brought up	£60,385
To a shuttle for taking in water, as occasion may require, from Redburn, and an over-fall for discharging the overplus water	- - - - -	20
To two miles of trenching, in bringing Kylsith burn, together with Shawen burn, into the canal of partition, which, at one shilling per yard running, comes to £176; and allowing seventy-four pound for extra cutting, with such small tunnels and bridges as may be wanted under and over the same, together with a shuttle and over-fall for taking in the water, and discharging the superfluous ditto, this work will come to	- - - - -	250
To building a dam or weir across the Kelvin below Inch Belly Bridge, with proper shuttles for drawing the water off occasionally	- - - - -	500
To building a ditto below Calder Bridge	- - - - -	500
To an aqueduct bridge for crossing the river Allander, and extra banking there	- - - - -	300
To extra work in piercing and vaulting a passage through the high ground, between Canny's burn and St. German's Loch	- - - - -	1200
To extra work in passing Grascuddon	- - - - -	100
To extra work in making a jetty to defend the mouth of the canal, and clearing the passage into Clyde	- - - - -	150
To five public road bridges, viz. at the road from Falkirk to Carron, at Camelton, at Castle Cary, at Canny's burn, and a Yocker, at £100 each	- - - - -	500
To twenty-one bridges, where the lesser roads intersect the canal, at seventy-five pounds each	- - - - -	1575
To private bridges that may be wanting for preserving the communications between the lands, No. 28, making, with the public road bridges, at an average, two in a mile, at fifty pound each	- - - - -	1400
To thirteen large tunnels for communicating the lesser brooks under the canal, at forty pounds each	- - - - -	520
To sixty-eight small tunnels for preserving water-courses, making, together with the large ones, at an average, three in a mile, at ten pound each	- - - - -	680
To making towing-paths, back drains, gates, towing-bridges, &c. at per mile, twenty pounds	- - - - -	540
To bringing the water of Enrick from a little above Randeford, into Carron	- - - - -	150
To bringing the burn of Ballagin, with some springs rising out of the hills to the west of the spout of Ballagin, into Kelvin	- - - - -	100
To temporary damages to lands and mills, impediments and works, unforeseen accidents, engines, utensils, and supervising	- - - - -	10,000
	Total	<u>£78,970</u>

APPENDIX.

AS the noblest work of the kind that ever has been executed, viz. The Canal Royal of Languedoc, has been generally esteemed not to answer the expence, this will undoubtedly be made an argument against the present proposition, I shall therefore oppose some matters of fact relating to the French canal by way of parallel.

Canal of Languedoc.

Length of the canal between Port de Cette, on the Mediterranean, and Thoulouse, is 152 English miles, besides a river navigation from Thoulouse to Bourdeaux, which is above 100 miles more, so that the whole length of inland navigation is above 250 English miles between the sea ports.

Suppose the vessels make way, at an average, $1\frac{1}{2}$ miles an hour, the passage will take fourteen days of twelve hours each.

The perpendicular height of the point of partition is 639 English feet above the two seas.

The canal is navigated by 100 locks, of above eight feet rise each.

The expence of this undertaking has been £612,500 sterling.

Canal proposed between the Forth and Clyde.

Length of the canal between the Carron shore and Barns of Clyde, is twenty-seven English miles. Sea vessels going up to Carron shore, and to Dumbarton, the distance of which by the canal will be thirty-three miles, but reckoning from port Glasgow to Leith, the distance will not exceed seventy English miles.

Suppose the vessels to make way, at an average, $1\frac{1}{2}$ miles per hour, the passage will be but four days of twelve hours each.

The perpendicular height of the point of partition in the proposed canal, is 145 feet.

This canal is to be navigated by seventy-seven locks, of between three and four feet rise each.

The expence of this undertaking is estimated at £78,970.

This

This work is still incomplete, by reason of shoals in the river Garonne, below Thoulouse, which, in dry seasons, greatly interrupts vessels, to carry the canal below which, as the only remedy, is estimated to cost £43,750.

This canal drops into the rivers Carron and Clyde, in the tides way, in places where there will be no obstruction to the vessels proposed to navigate the canals in the dryest seasons, at high water, to proceed upon their voyage to their respective sea ports.

Now, if it may be admitted, that as great a trade is likely to be carried on between the Forth and Clyde, where the sea navigation is long and dangerous, the inland short and easy, as between the Gulf of Lyons and the Bay of Biscay, where the sea navigation is open at all times, though long; the inland navigation tedious, and, at some times, almost impassable for want of water over the shoals in the river; the inference is very plain; that the same tolls which will hardly keep the French canal in repair, will make this a very beneficial undertaking to the British adventurers.

POSTSCRIPT.

First. On further considering the matter of the foregoing report, I am of opinion, it will be eligible to carry Redburn into the canal of partition, not as a subsidiary expedient in case of need, but to be applied in the first construction; the charge thereof will be amply recompensed by the omission of five locks between Redburn and Inch Belly Bridge; for the three feet locks proposed in that district may then be four feet, the same as all the rest; and it will appear from what has been said above, that the water expended on the whole, will be precisely the same: so that then the number of locks will be thirty-six each way, and in the whole seventy-two.

Secondly. Since the foregoing report, with the preceding article, by way of postscript, was delivered to the honorable the trustees for fisheries and manufactures in Scotland, Mr. Smeaton has discovered that, notwithstanding the care and pains he took to be correct, he has committed an error, in supposing the Scotch chain, with which the measures of the length of the tract for the land were taken, to consist of seventy feet each, whereas, in reality, it consists of seventy-four, this difference will not, however, in any respect affect the general principles upon which the preceding scheme is built, nor the estimate in any articles, except where the length of the canal is concerned. This length now appears to be $28\frac{1}{4}$ miles instead of 27, as before supposed, and this addition
of

of $1\frac{1}{4}$ mile, will affect the estimate in the whole £1322. 10s. but as by the foregoing article of postscript, there will be a saving of at least £1600, the estimate upon the whole will be rather less than greater, in which there is ample allowance for contingencies.

N. B. The true measure of the canal is 2010 Scots chains, which, at seventy feet per chain, comes to twenty-six miles, five furlongs, seven poles, $4\frac{1}{2}$, this, for a round number, was called twenty-seven miles, but at seventy-four feet to the chain, makes almost $28\frac{1}{4}$ English miles.

J. SMEATON.

Comparative ESTIMATE between a canal from Forth to Clyde, for vessels of forty tons, and for those proposed in the contracted scheme.

	£	s.	d.
Estimate, as it stands in Mr. Smeaton's report	79,970	0	0
To this add the expense upon additional length, as mentioned in the postscript	1,322	10	0
Sum total	82,292	10	0
Deduct as follows:			
Saving in making of thirty-six locks, of eight feet high, instead of seventy-two of four feet	9,200	0	0
Saving by half a foot depth of canal	1,678	0	0
Ditto, by extra digging, in widening the canal of partition, which, as there will be plenty of water in proportion to the work, will be unnecessary	667	0	0
	11,545	0	0
	68,647	10	0
Saving, by making thirty-six locks of ten feet wide instead of eighteen, at £75 each	2,700	0	0
Ditto, by making the canal twelve feet narrower, and one foot shallower, than supposed in my estimate, by which means it will be equally accommodated to boats of nine and a half, as I have supposed for seventeen and a half	8,076	0	0
	10,776	0	0
Saving			

	£	s.	d.
Brought over	10,776	0	0
Saving, by purchase of lands, the whole width being thirty-two feet instead of forty-eight, one-third must be deducted, amounting to	2,918	10	0
Ditto, by bridges, tunnels, and other extra articles, amounting in the whole to £9,095, one-sixth thereof I suppose will be saved	1,516	0	0
	<u>15,211</u>	<u>0</u>	<u>0</u>
The reduction of several articles, as before	15,211	0	0
Reduction of £10,000 allowed for contingencies, in proportion to the above reduction	2,594	0	0
	<u>17,805</u>	<u>0</u>	<u>0</u>
The first estimate reduced on account of water	68,647	10	0
Difference in the value of a canal, according to the dimensions proposed for a little one	<u>£50,842</u>	<u>10</u>	<u>0</u>

This sum is £100 too little, but was so delivered in.

QUERIES proposed by the Right Honorable Lord CATHCART.

1. Is not the best way to render the Leven navigable, the removal of a bar where it issues out of Loch Lomond, which would lower the lake ten feet perpendicular, and reduce the fall into the Leven ten feet, which would facilitate the making two locks and dams to complete the navigation?

2. Is it not probable that the grounds gained off the lake in this manner would do more than answer the expense of removing the bar? and is not £4,125, a proper charge for ten feet of lockage, and two and a half miles of artificial navigation in the Leven?

3. Is it not probable, that were the channel of the Forth straightened from Alloa to Offring, the tide would rise to that place, as it is but eight feet above the level of the present neap tide above Stirling Bridge, and the tide which comes from Leith to Alloa, in three quarters of an hour, takes the same length of time to go up to Stirling Pier, which is not four miles in a straight line, and a quarter of an hour from thence to the Bridge which is but a few yards when straightened? And would not the ground gained by this operation in all probability answer the expense of it?

These rivers, made navigable either by the method proposed, or some better expedient, it is to be considered, how the junction of the two seas can best be made; whether, by the Carron canal, or joining the Forth to the Enrick and Leven, or by carrying goods over land from Forth to Enrick?

Is it not better to cut a canal from the upper part of Leven to Oatter along the ground, which will be uncovered by lowering the lake, than to navigate the lake, which is tempestuous, and the Enrick, which will be difficult to enter at the mouth, after the lake is lowered?

4. Does it appear impossible to run a level drift from that part of the Enrick where he proposed to insert his canals under the summit of Bollat, and issuing out of the hill on the side next the Forth, and pointing towards Cardross, the said drift not exceeding two miles in length, and gaining one hundred and twenty-nine feet of perpendicular height?

The

The reason for believing this possible is the description of the ground in Mr. Smeaton's report, which says, the distance from the Enrick to the summit of Bollat is one mile, the height one hundred and twenty-nine feet; that from the summit the ground falls towards the Forth, and it is apprehended in a proportion not unlike that in which it rises from Enrick; in that case the drift would be the base of a triangle, the sides of which would be two miles, and therefore would itself be less than two miles.

5. Might not two hundred and two feet of height be saved by a drift of four miles from the level of Oatter, and coming out somewhere in the channel of Keltie burn?

6. What ought the dimensions of such drifts to be, in order to carry the canal through the hill at one or the other of these points, and what, at an average, might be the expense?

The rubbish will certainly be drawn up to the surface through pits made for that purpose, which will not be deep; and, therefore, it is apprehended, the length of the drift ought not to increase the proportion of the expense; it is also imagined, in such a drift, a towing-path would be unnecessary.

7. Would it not be a shortening of the navigation, both in the Bollat and Oatter passages, to join the Forth at Cardross, rather than Offring?

8. Supposing that the public, or that private adventurers were to undertake the Carron canal, how long would it probably be before the said canal could be navigated, and what would be the tolls, or rather, what would be the sum of the toll necessary for re-imbursement and repairs?

9. Supposing the Oatter passage to be undertaken, how soon would it be practised?

10. If the Bollat or Keltie passage were to be made choice of, the Oatter passage would be a part of either; but though the Carron passage were pitched upon, would the temporary advantage, and the eventual resource of the Oatter passage, in case of accidents in the Carron canal, together with the toll which would arise from it before the Carron canal could be finished, be proper and safe motives for laying out £12,000 upon it?

11. How many men and horses are required to draw a ga boat of forty tons?

ANSWER to the queries proposed by the Right Honorable the Earl of CATHCART to JOHN SMEATON, engineer.

TO the first. I apprehend it would be a very difficult and expensive piece of work to deepen the channel of the Leven, so as to reduce the water of Loch Lomond ten feet, because the water of the loch is not held up by any one single shoal, but by a succession of shoals from the mouth of the loch, to within a mile of Dumbarton, all of which I apprehend must be deepened in different degrees, in order to produce the desired effect. There is indeed a bar or shoal in the mouth of the lake, which would pen the water, in case the shoal next below the boat of Balloch was removed, which now pens the water over the shoal at the entrance; and from the extension of width in that place, the water is nearly stagnant: but suppose both these shoals removed, the water would still remain penned up by the natural bottom of the river, which is in general shallow from thence quite to the tides way; and supposing the whole cleared away to ten feet below the uppermost shoal, unless the section of the river were very much increased, the natural declivity of the surface, requisite for discharging so great a quantity of water, would still produce a pen upon the water of the loch.

The deepening of rivers for any extent I have found a very tedious and expensive piece of work; and, in short, I see no means of reducing the water of the loch at the same, or, indeed, any thing near the same expense, as making it navigable by locks and dams.

Secondly. How far it might answer with respect to the drainage of the bordering lands, I cannot be a judge, unless I know the quantity and value of the lands that would be uncovered by a certain number of feet reduction, having never seen any part of the coast, except about the mouths of Leven and Enrick; but it is probable that if a quantity of land were drained hereby, the land-owners would, with great difficulty, be brought to pay for the improvements: £4,125 is the average expense of ten feet of lockage for $2\frac{1}{2}$ miles of artificial navigation; but I am of opinion, double that sum would not draw off ten feet water from the surface of the loch, nor would this lockage be saved, if the navigation were carried further, for what is subtracted below must be added above.

Thirdly. But I apprehend the gained lands would by no means defray the expense of making the cuts; because it would be some years before the old loops would be-

come land, and a good deal of present land would be converted into water; besides, the great depth of cutting required, would make the work turn out a greater expense than the making a new canal for navigation only from Offrings to Alloa.

This may appear at first sight a paradoxical position, but if it be considered that the surface of the water in the channel of the Forth, above Craigforth mill, is in general ten feet within foil, and I suppose in general twenty feet depth of water; the new cuts would in general be twenty feet deep to make them equivalent with the old river, which I take from view to be eighty feet wide at a medium, and as I suppose at least one-third must be new cut to make it tolerably straight, the expense would be much greater, width and depth considered, together with the drainage of the water, for what lies below the river's surface, than digging a new canal sufficient in width and depth for the purposes of navigation only. It perhaps may be imagined that digging the cuts of small dimensions, and down to the water's surface at first, may suffice, and that the current will wear out the cores below water, and widen the channels; but though this might be the case between Alloa and Stirling, where the tide runs slow, yet above it would be so checked by those narrow obstructions, that the water being obliged to follow chiefly the old course, would be spent in the meanderings, and the proposed effect destroyed, and as the reflow of the waters from the country would in like manner take that course which upon the whole would be easiest; it would probably be many years before the new cuts would be wholly converted into a current river, unless the old loops were entirely shut up by dams, which would still greatly increase the expense.

4th, 5th, 6th, and 7thly. It is difficult to say what cannot be conquered by art, industry, length of time, and unlimited expense, except such things as are impossible in nature, of which kind I do not reckon the piercing the hill of Bollat, or that between Lomond and Keltie, with a navigable passage, but this kind of work generally turns out so very expensive, and so very uncertain in its expense, that I think it should not be undertaken but in cases of absolute necessity. That it will be a great and expensive work to make a navigable canal, which must be at least twenty feet wide, and at least two miles under ground, we are very sure, and the most eligible case of it is where there is a free stone rock sufficiently soft to make it work easy, and sufficiently compact to make it stand without supporting; in case it is softer, so as to make it necessary to arch it, it greatly adds to the expense, but in case it should prove gravel, or any other loose kind of matter, it will be very difficult to get it to stand, 'till it can be supported by an arch; and if a running sand, so far as I am acquainted, impossible, without opening it from the top, which, though not impracticable at a great depth, is excessively expensive;

expensive: on the other hand, if it should turn out a hard whinstone rock, so as not to be worked without blasting, the work would not only go on very slow, but vastly expensive, one furlong of which, or a running sand, might overset the undertaking after the rest had been successfully executed.—Drains for coal-pits or mines are much more easily managed, because, being of small dimensions, if of soft matter, they are more easily made to stand till supported, and if of middling or hard, there is less matter to cut.

In the canal of Languedoc, a hill was pierced for the navigation to pass, and made wide enough for a horse-path by the side of it. The passage was pierced through a soft rock, thought at first sufficiently firm to stand by itself, but has since been obliged to be supported by an arch, as I have been informed; what might be the cost of it I know not, but this is certain, that though the extent in our measure be not above 256 yards, yet it is accounted one of the prodigies of that very expensive undertaking. The Duke of Bridgwater has lately made the drain of his colliery navigable, and it is carried upon the same level as his canal; but the subterraneous navigation is only $5\frac{1}{2}$ feet in width; and they were near two years in advancing it half a mile, though no part of it needed blowing: yet many parts were obliged to be supported by walls, and an arch of brick: what the particular expense has been, I have not been informed, but imagine it not a trifle, nor is it in any degree to be compared with one near four times the width.—To pretend to give an estimate for a work of this kind without any data of quality of soil, which it is not easy to know before hand, would be so very vague, that I can hardly tell how to set pen to paper in the way of calculation. It may be imagined perhaps that a hole, pierced the size of the Duke of Bridgwater's, might answer the end, but the inconvenience of twice altering the bulk, with the expenses contingent thereon, will be considered under another head.

Eighthly. I apprehend that supposing as many men could be set to work as could conveniently be properly superintended, the Carron passage might be completed in six or in most seven years, but the difficulty of supporting and maintaining the necessary number of men (suppose 250) upon the works, in the parts of the country where any of the passages are practicable, is an article of consideration; for if they were obliged to be lodged in barracks, the charge of building and removing them, will be a further article of expense.

As to the money to be raised by way of toll, £4000 per annum is the interest of £80,000 at five per cent. but if undertaken by private adventurers, it should be by no means

means limited to that sum, as has been done in most of the late Navigation Acts passed for England; but that if the tolls will bear it, to give the adventurers the prospect of making ten per cent.; this not to be exceeded: but I apprehend absolutely requisite, in order to draw the necessary supplies out of private pockets. In this light, it will never be practicable to reimburse the principal, because if it affords less than five per cent. the means are wanting, and if more * unjust, nor indeed is there any reason for it, because the increase of tolls to be taken in order to produce the reimbursement, must be an additional load laid upon the present generation, who are supposed to contribute the whole, in order to ease the succeeding, who will have the benefit of this great work done to their hands, and only have to raise the interest to maintain and support it, which the benefit their trade will receive will insensibly do.—But if done at the public expense, then I suppose it will be thought equitable that the public money should be reimbursed, and in order that it should be done in some reasonable time, the tolls should clear at least £8000 per annum.

With respect to repairs, they would greatly depend upon the first execution, but suppose this done reasonably well, as I have supposed in my estimate, I look upon it, after every thing is completed, that two gangs of ten men each, with an overseer to each gang, and a general surveyor of the works over them, will keep the works in order as to common repairs.

This I have fully stated in the enclosed copy of an estimate I have drawn out for the service of the Board of Trustees, which amounts at the utmost to £1600 per annum, supposing that provision is made from the first, for the great repairs that in time must be wanted, but if the current expenses only are raised at first, and the other committed to the increase of trade, that must in a manner necessarily take place, then the sum of £1136 per annum is the sum required.

Ninthly. I suppose the necessaries for the Oater passage could not be executed in less than three summers, as the first is commonly consumed in getting the works in motion.

Tenthly. I think from what has been already advanced upon the former heads, that it would be by no means worth the while to complete the Oater passage, with a view to serve as a temporary expedient till the Carron passage is perfected, for before the trade

* If I expose my money to loss upon the uncertain prospect of gain, 'tis apprehended to be unjust to pay off the winning stake, as the tolls may be lowered in proportion.

trade could get into a settled tract at Oater passage, the Carron passage would be completed, and if expected, would hinder the merchants from turning their attention so effectually upon the benefits that might accrue from the other; for though it might be very eligible, upon a separate plan, to make both the rivers Leven and Forth navigable, yet to effect a communication over land, two additional large warehouses, with additional clerks for the receipts and deliveries, must be planted at the head of each, and all the apparatus necessary for land carriage must be provided, all which in a great measure would be useless when the Carron passage was completed: and as to serving in case of accident, there is hardly any accident that can happen in the common course of things, but would be sooner repaired than the hands and apparatus necessary in the other passage could be got in motion: for supposing a lock wanted rebuilding, which is the greatest stoppage that can be expected, the work is not begun till every thing is ready, and then vessels being planted on both sides, the goods are delivered over from one to another, which is certainly much less trouble than to employ two warehouses, two clerks, and a land carriage of five or six miles between; nay, it is much to be questioned whether, with such an interruption of the water carriage, goods would not be carried cheaper by land the whole way; for suppose the Carron passage interrupted by a space of five or six miles in the middle, which could not be made navigable, I apprehend that goods could be carried cheaper by land the whole length, than by this compound carriage; for the altering the bulk is not only a great expense and loss of time, but by interrupting the certainty of the delivery, much less eligible to merchants: for, besides the expense of two additional warehouses as before stated, there will be the loading and unloading of a vessel, and the loading and unloading of the land-carriage extra in this method of conveyance, and for want of carriages and vessels keeping exact time with each other, neglect of clerks, and the like, if a merchant puts a quantity of goods on board at one end of the canal together, he never could be certain that they would be delivered together at the other end, or in due time.

An experiment was tried in our river this winter: the town of Brighthouse, at the present head of the navigation, fetch their coals by land-carriage five miles, from a place within half a mile of the river: some cargoes of coals were brought up by water, and though the tolls upon coals are but one quarter of merchant's goods, yet they could not deliver them cheaper than by land-carriage, for the loading and carriage down to the river side, and the loading and carriage from the river to people's houses, together with freight and tolls, made the coals rather dearer than if fetched by
land

and carriage from the pits, and yet the tolls were no more than one half-penny per ton per mile.

Eleventh. I apprehend two men and a boy, two horses and a driver, will be necessary to navigate a ga boat of forty tons.

ESTIMATE of the expense attending the maintaining and preserving of the canal from Forth to Clyde by way of Carron water, and also for collecting the tolls thereof.

	£	s.	d.
To sixteen labourers, at one shilling per day each, (or their equivalent in men whose labour is reckoned at a different rate), their wages per annum will be fifteen pounds, twelve shillings each, and for sixteen, - - - - -	249	12	0
To two masons and two carpenters, at one shilling and sixpence per day each, (or their equivalent), which comes to twenty-three pounds, eight shillings, per year each, and for the four, - - - - -	93	12	0
To two overseers, at forty pounds per year each, to take account of the time, and oversee to the works of the above men, supposed to be divided into two gangs, - - - - -	80	0	0
To a surveyor per annum, for directing the repairs of the whole, - - - - -	80	0	0
To workmen's wages, - - - - -	503	4	0
The tolls and materials consumed by the working hands, I suppose will be equivalent to their wages, the two first articles will therefore be - - - - -	343	4	0
Expense of common annual repair, - - - - -	846	8	0
To the clerk for collecting the tolls from the toll-gatherers, and paying the same to the treasurer once a month, and keeping the accounts relative thereto, per annum, - - - - -	80	0	0
To two toll-gatherers, one at each end of the canal, at forty pounds per year each, - - - - -	80	0	0
To one ditto at the point of partition, - - - - -	30	0	0
To six men stationed as lock-keepers on different parts of the canal, to be a check upon the bargemen from doing damage to the works, by running against the lock-gates, leaving the clough running, so as to let off the water, &c. at three shillings and sixpence per week, - - - - -	54	12	0
To books, paper, &c. per annum, - - - - -	15	0	0
To letters, messengers, and other contingent expenses, - - - - -	30	0	0
To clerks, toll-gatherers, lock-keepers, &c. - - - - -	289	12	0
			To

	£	s.	d.
Brought over	289	12	0
To common annual expenses,	846	8	0
Common annual expense,	1136	0	0
Supposed to be laid by every year, to answer the above, and for the purposes after mentioned,	1600	0	0
Then the annual overplus will be	464	0	0
This, in twenty years, will amount to	9280	5	0
I suppose in twenty years time many of the locks will want new gates, all which will gradually fail in a few years after, I therefore suppose them all made at the end of twenty years, and therefore seventy-two locks at sixty pounds per lock,	4320	0	0
The bridges, and other works of timber, will likewise want repair, which I suppose upon the whole to amount to one-sixth of the locks,	720	0	0
Sum of these repairs,	5040	0	0
This, taken from the above accumulated sum of £9280, leaves in hand at the end of twenty years,	4240	0	0
The interest of this sum for twenty years more, at three per cent,	2544	0	0
The accumulation of the overplus sum of £464, will, in the second twenty years, amount to, as before,	9280	0	0
Money in hand at the end of forty years,	16,064	0	0
The second set of lock-gates will, at the end of twenty years more, want renewing as before, and as the thresholds will want renewing also, I estimate the repairs at seventy pounds per lock; this, for seventy-two locks, will be	5040	0	0
And as the second repair of other work may be in the same proportion, that is, one-sixth of the locks, this will be	840	0	0
Repairs wanted at the end of forty years, which deduct from the above sum on hand,	5880	0	0
Remains in hand at the end of forty years,	10,184	0	0
The interest of this sum, at three per cent, for twenty years,	6110	8	0
The accumulation of the overplus sum of £464, will, in the third twenty years, amount to, as before,	9280	0	0
Money in hand at the end of sixty years,	25,574	8	0
			At

	£	s.	d.
Brought over,	25,574	8	0
At the end of sixty years I suppose the locks in general may need re-building, but as the greater part of the stone, and some other of the materials may be of service, and the excavation ready made, I suppose they may be as good as at first, for £300 each, at an average, therefore, will cost	21,600	0	0
And if we suppose the other works to follow in the same proportion as before, they will cost, to make all good as at first,	3,600	0	0
To making all the works as good as at first, at the end of sixty years, which deduct from the money in hand,	25,200	0	0
There remains an overplus in hand, at the end of sixty years, after every thing is made as good as at first,	374	8	0

N. B. In the preceding estimate I have endeavoured to shew what sum of money applied from the beginning, will preserve the work to perpetuity; but I apprehend this to be altogether a needless supposition; for if the work will defray the common expenses and repairs for the first twenty years, viz. £1136 per annum, there is no doubt but that the increase of trade naturally following the use of these undertakings, will answer the greater repairs that must afterwards follow.

J. SMEATON.

Austhorpe, 22d December, 1764.

To the honorable the board of trustees for fisheries,
manufactures, and improvements, in Scotland.

MINUTES concerning Forth and Clyde.

WHEN Mr. SMEATON was applied to to survey the canal from Forth to Clyde, no estimate was given him of any quantity of tonnage that might be supposed yearly to pass from one Firth to the other; and being generally supposed, that the great difficulty would be to provide water for the necessary tonnage, the great object of his report was to shew how large a tonnage of goods might be navigated with the water that was clearly and certainly producible; and that to work the largest size boats, that, in his opinion, would be convenient for an artificial navigation; upon that proposition, he formed his estimate, observing, at the same time, "that if in the execution it should appear, that the supply of water should turn out more liberal, or a less number of vessels be expected to navigate than he had supposed, (that is, supposing a lesser tonnage to pass than computed upon), then some expense may be saved by making the locks greater in general (that is higher) and without preserving a strict equality." The highest lock determines the quantity of water to be used.

The quantity of tonnage that this canal was estimated to be capable of navigating in the driest seasons, was 208,000 tons a year; but the quantity expected, it seems, is not above 25,000, which is short of one-eighth part of the quantity computed upon; so that hence, it appears, the locks may be of any height that convenience may suggest. I am very far from thinking that 25,000 will be the whole annual tonnage of the canal, if executed, to carry such vessels as I have proposed; but supposing four times as much, that is, 100,000 tons per year; then by the same rules, the locks may, instead of four feet, be made eight feet high, this would reduce their number to thirty-six instead of seventy-two; and as an eight foot lock may be built as well for £600, as a four foot lock can be built for £400, the whole expense in this article only will be reduced to £9200.

It is mentioned in the report, that the canal is proposed to be dug one foot deeper than the draft of water which the barges will draw, in order that the canal may be a reservoir within itself, to answer the exhalations in dry seasons; but it appearing from the reduction of the supposition of tonnage, that there will be a great deal of water to spare, the extra depth on this account will be unnecessary, and as six inches beyond their draft of water is very sufficient to allow the vessels freedom of motion, the whole canal may be reduced six inches in depth, which will produce a saving of £1678, the article of widening

widening the canal of partition, will also become unnecessary, amounting to £667. Therefore, after adding £1322. 10s. the sum by which the estimate is affected on account of an increase of length, (see postscript, page 54) and deducting the above articles, the estimate will then become * £68,647. 10s. 6d. to execute the plan first proposed, that is, to carry ga boats of forty tons.

In order to come at the merits of the question, let us now see what reduction can be made by a supposition of using vessels eight feet narrower, and drawing six inches less water than according to the former suppositions; and deducting the value of those savings, according to the former estimate, we shall have the true comparative value of the two plans; for to compare, according to the estimate of different persons, working from different dimensions, and supposition of prices, can never be a true comparison at all, for whatever may be saved by working cheaper, is equally applicable to the plan proposed by Mr. Smeaton; as by the new proposed canal, and therefore leaves the difference nearly the same.

Supposing then the locks to be of the same height and number as above proposed, viz. thirty-six of eight feet high each, the same in the smaller canal as in the larger, (which is a supposition in favour of the small canal, as the multiplying of locks can never lessen the expence) as the walls of the smaller locks must be of the same height and thickness, and nearly of the same length, they must be of the same strength; there will therefore be nothing saved but in the width of the gates, the floor and the excavation; the whole of which, as nearly as I can judge, will be about £75 per lock, which for thirty-six, amounts to £2700.

The width of the canal may with propriety be about twelve feet less for a $9\frac{1}{2}$ feet boat than for a $17\frac{1}{2}$ feet boat, and drawing three feet six inches water instead of four feet; it may be half a foot shallower: the difference of these dimensions will at the same prices produce a saving of £8076. 10s.

The ground occupied will be less in breadth by twelve yards, which, upon the whole canal, at the same price per acre, saves £2918. 10s.

The difference in the bridges, tunnels, and other extra articles, affected by a difference in width, I estimate at £1516.

* This sum is wrong, see page 55.

The sum total of these four articles of saving is £15,211; but as it may be supposed that the round sum of £10,000 at the tail of my estimate, for contingent expenses, will be proportionably less upon a lesser work, the proportional reduction on this account will be £2594, which, with the saving before, amounts to £17,805 difference between the two plans. They will then stand thus:

	£	s.
To execute the greater canal to carry ga boats $17\frac{1}{2}$ feet wide, and drawing four feet water, of forty tons, as first proposed, having plenty of water, - - - - -	68,647	10
To execute the less canal for boats of $9\frac{1}{2}$ feet wide, and three feet six inches draft of water - - - - -	50,842	10
Difference - - - - -	17,805	0

which is a saving of little more than one-quarter of the sum necessary for the greater canal.

But if, instead of reducing the depth of the greater canal six inches, we suppose the vessels to load down to four feet six inches, then as there will be no fear of wanting water, they will carry twelve tons more, and occasionally may draw four feet nine inches, which will enable them to carry eighteen tons more.

As I was unwilling to over-rate any thing in my report, I have called the tonnage of the vessel therein proposed forty tons, but in reality they ought to carry at four feet draft of water forty-eight or rather fifty tons neat weight; but as the water carriage is often lumped, and more than neat weight carried, that nothing might fall short in practice, I called them in round numbers forty tons; reckoning therefore, according to neat weight, four feet will carry forty-eight tons; four feet six inches, sixty tons; and four feet nine inches, sixty-six tons.

By a like computation, a vessel fifty-five feet long, $9\frac{1}{2}$ feet wide, and drawing three feet six inches water, may (lighter built) carry in smooth water, upon the canal only, thirty-three tons neat weight; but if built so as to sail upon the Firths, cannot carry above $26\frac{1}{2}$ tons: a vessel also of the same width and depth, but thirty-six feet long, may (lighter built) in the canal, carry $20\frac{1}{2}$ tons, but built for the Firths, not above $16\frac{1}{2}$ tons neat weight.

Supposing

Supposing the canal to be of the depth originally computed upon, in order from the surplusage of water to take an advantage of a superior tonnage of vessels; the article of reduction arising from six inches depth of water, must then again be added; the account will then stand thus:—

	£	s.
To making a canal from Forth to Clyde, for vessels $17\frac{1}{2}$ feet wide, drawing four feet six inches water; and navigating the Firths equally with the canals, and occasionally the coasts in summer, of fifty tons burthen - - - - -	70,335	10
To making a canal from Forth to Clyde, for vessels of $9\frac{1}{2}$ feet wide, and drawing three feet six inches water, and navigating the Firths, (I apprehend with much less safety, and the coasts not at all) of $26\frac{1}{2}$ tons - - - - -	50,842	10
Difference of expense - - - - -	19,493	0

The merits of the two plans I leave to others to determine.

It is to be observed that the charge of carriage of goods does not depend upon the toll of the canal, but of that with freight, and other charges conjointly.

It now remains to explain a passage in my report:

“ I found that a middling ga boat of fifty-six feet length, stem and stern, $17\frac{1}{2}$ wide, and drawing four feet water, will carry at least forty tons; and this I look upon to be the largest size that will be convenient for an artificial navigation.”

I never meant by these words to limit the size of vessels fit for any artificial navigation; nor do I in fact determine any thing, but my own opinion was, that this was as large a size as would be convenient for an artificial navigation so circumstanced in regard to water, trade, and prospect of funds to execute.

That this was the largest sized vessels that could be carried upon an artificial navigation, would have been very absurd in me to say, having very frequently asserted the possibility in point of art, to carry first rate men of war across this tract; but in this scheme I paid more regard to what I thought was fit and likely to be carried into execution, than what was possible in itself; and this is not determined any way otherwise than as a matter of opinion at that time. So that if any body afterwards should be able to prove the expediency of larger vessels, I have no hesitation of the possibility of performance.

performance. As to the increase now mentioned, it is not a new thought; but what I saw as clearly at that time as now; and imagine every body, (being nothing more than a deduction of common sense) would see as clearly as myself.

In fine, though after the lapse of nearly four years, my ideas may be presumed to be extended; yet I have no great reason to vary my opinion much on this point; for I conceive, that after having provided a passage for such vessels as can navigate both the Firths, very well and safely, and coast occasionally; that to extend the canal to such dimensions as to navigate vessels capable of going foreign voyages, would so greatly enhance the expense, that considering the quantity of goods coming under this denomination only, the additional convenience betwixt going through and reloading, would no way answer the interest of the additional capital; and if not, I consider it to be no matter whether the money goes from public or private hands, for if the former, the sum had better be applied to cheapen those means that are naturally adapted to do the business the cheapest way.—After all, this being a matter not within my profession as an engineer to determine, whenever the contrary is clearly evinced to the satisfaction of those whom it may concern, I readily submit.

ESTIMATE of the probable expense of executing a canal through the tract formerly proposed by Mr. Smeaton, from Carron shore to Barns of Clyde, for vessels drawing eight feet water, twenty feet wide and sixty feet long, and upon a supposition that at a medium, each lock full of water passes fifty tons of water from west to east, and twenty-five tons from east to west, and to navigate at this rate 100,000 tons per year.—

For vessels of twenty feet wide, I suppose the canal to be twenty-seven feet bottom, and $8\frac{1}{2}$ deep of water, and at an average $10\frac{1}{2}$ feet deep, within soil; this, with slopes, as in the former estimate, will make the width at top sixty-two feet; this, at 5d. a cube yard at an average, will come to £1906. 13s. 4d. per mile, and for $28\frac{1}{4}$ miles	£
	53,864
The width of the canal at top being sixty-two feet, and as the matter cannot be heaped up so high in proportion to the depth of the canal, as when it is shallower, instead of allowing twice the breadth for the canal for depositing the matter, I think it necessary to allow three times, so that the whole width over all will be eighty-three yards; this will contain $30\frac{2}{5}$ acres per mile, and for $28\frac{1}{4}$ miles, $853\frac{2}{5}$ acres, which, if purchased at a medium of £20 per acre, as before supposed, comes to	16,064

Carried forward	69,928
-----------------	--------

Supposing

	Brought over	£ 69,928
Supposing the vessels to have their bowsprits to turn up, or unship, then the locks need not be above seventy-two feet long, and being $20\frac{1}{2}$ feet wide, they will pass (in vessels at a medium capable of carrying fifty tons, as before mentioned) 100,000 tons annually, and the locks may be of eight feet rise; but being of greater depth and strength than before required, they will probably cost £1000 each, and being thirty-six in number, will come to		36,000
The extra cutting, banking, bridges, tunnels, and other works, including contingencies in the former estimate, comes to £23,178, but for this work I estimate them at double, which will therefore be		46,356
		152,284

N. B. If small locks are made by the side of the former for lighters, they will cost about half as much as the great ones, that is, an addition of £18,000; and if the vessels are made with fixed bowsprits, the locks must be made considerably longer, and will therefore cost more money, and navigate less shipping, unless the locks are also increased in number.

INSTRUCTIONS for Mr. MACKELL relative to the proposed Canal from Forth to Clyde.

Mr. MACKELL is desired by Mr. SMEATON to examine afresh all the circumstances relative to the tract of the intended canal through Dolater bog, and of the resources for supplying the same with water; and if the time will allow to get the level formerly taken by Mr. SMEATON verified, also to examine the different tracts or passages, whereby the canal proposed by Mr. SMEATON, to terminate in the Carron shore and barns of Clyde, may be extended to the Forth of Clyde into deeper water; and to examine the foundings of the two Firths, till every impediment is incontestably out of the way of all such vessels as are proposed to navigate upon the said canals. To examine the matter or soil of the fords or shallows where obstructions are likely to happen, and particularly such as lie below the mouth of Dalmoore burn, upon the Clyde, as also Erskin sands, and Dumbuck ford, with the length of space that each impediment continues.

Also, to examine wherever any difficulty shall appear likely to arise, in the practicability of cutting the ground, to the average of ten or eleven feet below the soil, whether

ther from rock, bog, mud, or running sand, to ascertain the same by boring, or such method as may appear from circumstances the most proper in each particular case: also particularly to note the most proper tract for carrying the canal from Grascuddon to Dalmoore burn, how far the canal can be carried below the same, and what difference of depth of water can be obtained by such further extension, and particularly, if the canal can be carried into Clyde below Erskin sands.

To examine likewise the tracts and levels of the grounds most proper for carrying off the branch canals to Glasgow and Borrowstones, noting the length of base and section of such grounds as are likely to be above the level of the canal; and also the breadth and section of such hollows as must necessarily be filled up or banked, in order to support the canal across the same, with all such circumstances as appear to Mr. Mackell proper to be enquired into, in order to ascertain the method of execution of the proposed scheme, and the true costs that may be likely to attend the same.

The above is desired to be done the first week in July, when, or as soon after as possible, Mr. SMEATON expects to be in the country, to examine the premises.

J. SMEATON.

London, 16th of May.

The Second REPORT of JOHN SMEATON, engineer, and F. R. S. touching the practicability and expense of making a navigable canal from the river Forth to the river Clyde, and thereby joining the east sea to the west, for vessels of greater burthen and draft of water than those which were the subject of his first Report.

HAVING, in my former report, endeavoured to explain as clearly as possible the general situation of this tract of country, together with the principles upon which a work of this kind must proceed; having also explained my reasons for preferring the Carron Passage to that by way of Loch Lomond, and it further appearing to me, that every argument against the Loch Lomond Passage holds the stronger, as the size of the canal is supposed larger;—I shall now confine myself to the Carron Passage, and to such points as the difference of the present design and circumstances likely to attend the execution, make necessary to be more particularly explained or enlarged upon. Supposing, therefore, my former Report, signed the 1st of March, 1764, in the hands of every one concerned, I shall consider this as supplemental thereto.

I must here beg leave to observe, that in the forming of the scheme that was the subject of my former report, I had no data to proceed upon, no estimate of quantity of tonnage, dimensions, or sorts of vessels proper to be used: my instructions from the honorable board of trustees, which were verbal, being, as I understood them, to give them a design for the sort of canal, that in my judgment would best suit the country, when taken in every point of view.

As I considered the making a canal across the kingdom from sea to sea, (though here the most practicable of any place I had seen), as a work of very considerable expense; to have made a design upon so large a scale, as to have stood no chance of being executed, seemed to me in no respect fulfilling the general purport of my orders. I had therefore no idea of designing a canal for sea-built vessels, proper for going upon foreign voyages, no such canal having yet appeared in any part of the world, and this being in a manner, the first attempt toward an artificial navigation by locks in Scotland.

My business, therefore, seemed to be to look out for the least sort of vessel that would safely navigate the two Firths, and occasionally go coastways. Of those I assigned the dimensions and tonnage, and those “I looked upon to be the largest size, that would

be convenient for an artificial navigation," for to make larger vessels and works, without making them proper for sea vessels, seemed to me to be likely to be attended with additional expenses, to which the difference of utility would be no ways adequate. This way of reasoning produced the above expression of limitation, not any appearance of natural impracticability: but this matter having been taken up by gentlemen versed in trade, who are of opinion, that a passage for sea vessels would be of great public utility, and that sentiment being espoused by the principal noblemen and gentlemen of the country, it now becomes probable, that sufficient funds, which before seemed the principal obstacle, may be raised for the execution thereof.

The proposition therefore now stands thus:

To ascertain the practicability, general design, and expense of a canal capable of navigating vessels drawing eight feet water, and of such as are sixty feet long, or twenty feet wide, with a supply of water for the passage of 100,000 tons of merchandize yearly, upon a supposition that two-thirds of the above quantity pass from west to east, and one-third from east to west, and that among different sorts of vessels, they carry, when loaded, fifty tons at a medium.

It is also proposed to carry off a branch to Glasgow of equal dimensions to the main canal, and to extend the canal at the west end as far down the river Clyde as Dalmoore's burn foot, at the least; also to extend it at the east end as far down as a place called the Hewk Farm, near the mouth of the river Carron.

I am also desired to consider what will be the difference of expense, in case the canal is made of seven feet, or of ten feet deep. These are the propositions or data upon which I am now to proceed.

As a necessary supply of water is the principal requisite, I shall begin with this point first.

If two-thirds of 100,000 tons of shipping pass one way, and the vessels return some loaded, some half loaded, and some empty, so as upon the whole to carry back half loads, or one-third of 100,000 tons, it will be the same thing in point of water, as if they carried two-thirds of 100,000 tons each way: now, two-thirds of 100,000 is $66,666\frac{2}{3}$ tons, which, divided by fifty tons, the average quantity of each vessel, gives $1333\frac{1}{3}$ for the number of trips made by the vessels altogether in a year; and

and as each vessel will take four locks-full of water for her passage backwards and forwards, that is, one at each end of the canal of partition going, and the same in returning with her half load, the number of locks-full expended yearly will be $5333\frac{1}{3}$.

The tonnage and number of vessels being considerably less than what was stated in my former report, the locks may be admitted of greater capacity, and perpendicular rise, as mentioned page 49, which will render the navigation more simple, and the stoppages less frequent. Supposing them now to be of eight feet rise each, to take in vessels of sixty feet long, and twenty feet wide, they should be seventy-two feet long, and $20\frac{1}{2}$ feet wide, which locks will contain 11,808 cube feet of water to fill them, this, multiplied by $5333\frac{1}{3}$ the number of locks-full in a year, gives the annual lockage of water equal to 62,976,000 cube feet, which, divided by 365, gives the expense per day 172,482 cube feet.

If we allow the leakage per day equal to four locks-full, as per former report, (page 41), then the leakage will be 47,232 cube feet per day.

With respect to exhalations, as the whole canal was before proposed to be dug one foot deeper than the draft of water proposed for the boats, and as also observed (page 41), the loss by exhalations does not exceed ten inches, the canal would have contained in itself a reservoir of supply thereof, but as we now propose, in order to save expense in extra digging, to make every advantage of depth of water, the exhalations must be otherways accounted for, and compensated. When deep standing waters lose to the amount of ten inches perpendicular, it must be in a long drought of three or four months continuance; now, if we suppose ten inches to be lost in 100 days, this will be at an average of one-tenth of an inch per day, which very well agrees with such observations as I have made since that time.

The whole extent of the canal will be about thirty-seven miles, and about $55\frac{1}{2}$ feet wide at the water-line, but to take in passing places, turning places, and other extra widths, we will take the average width at sixty feet; the whole superficies then will be 11,721,600 feet, which, at one-tenth of an inch deep, will contain 97,680 cube feet for the mean daily evaporation.

The soakage is a matter that it is impossible to make any estimate of, as it depends upon circumstances that cannot be allowed for; and though in sandy and gravelly ground it will at first be considerable, yet experience shews that in a moderate space of time,

time, these soils, when fully saturated and wrecked up with the sediments of the water, become as tight as other soils; and as in the course of the canal many springs must be expected to be cut, which will afford a supply of water, it is probable that the loss by soakage after a year or two will be next to nothing*. Yet, that we may not be deceived, I will suppose the soakage equal to the exhalations, which I look upon to be an ample allowance, the account will then stand thus :

			Cube feet.
Water expended by lockage per day,	-	-	172,482
by leakage,	-	-	47,232
by exhalations,	-	-	97,680
by soakage,	-	-	97,680
Total expense of water per day,	-	-	415,074

When I made my former report, it appeared, that the supply of water, even in the dryest seasons, was so superior to what was likely to be wanted for the locks then proposed, that I did not see it necessary to enter into the computations of some supplies that were but barely mentioned; but as we now want a supply of 415,000 cube feet water per day, instead of 152,000, as before set forth, page 41; and as the affair of water has been most in doubt, I shall endeavour to set forth this article more at large, and for this purpose, I have not only re-examined the supplies formerly mentioned, but shall bring some to account that I was not then informed of.

The burns or brooks that more immediately offer themselves for supplying the canal of partition, are the following :

1st. Achinclough Burn. 2d. Wineford coal-pit drain, or level. 3d. Redburn. 4th. The Garron Burn, which turns Kilsyth Mills, and in my former report, called Kilsyth Burn. 5th. Culeam Burn, not noticed before; this falling into Garron Burn, some distance below the mill, forms the Burn of Kilsyth. 6th. Shawend Burn.

First. The Achinclough burn, in regard to discharge of water, I find, as before represented, viz. that is, to produce 89,343 cube feet per day, in the dryest seasons.

Achinclough

* It is to be observed, on the article of soakage, that in soils subject thereto, those parts of the canal will be filled in rainy seasons, and kept supplied with muddy waters; so that it is to be reckoned upon, that all the most considerable leakages will be stopped before the canal is opened for use.

Achinclough mill has indeed lost half its water by its being diverted to another mill; but as this mill's water falls into Dolater bog, the whole quantity reckoned upon Achinclough Burn will remain the same.

2d. Wineford coal-pit drain is said to be constant the whole year; I gaged its water the 17th of August last, and it then amounted to 25,000 cube feet per day.

3d. Redburn has no mill upon it, so that it is not easy to say what its discharge may be in the dryest times; in common it is as big as Achinclough, which led me to suppose it the same at others, but on my last view I was informed that in dry weather it is far less, yet always has running water, and never less than Wineford coal-pit drain.

N. B. Castle Cary mill takes in all the preceding, but its dam head is so leaky that no conclusion can be formed therefrom in dry times.

4th. The Garron Burn is set down in my former report at 87,003 cube feet in dry times, but from information and measures taken on my last view, it comes out only 65,365. The miller last informed me that the late drought was one of the greatest he ever knew, yet it continued only to affect them with a scarcity of water betwixt seven and eight weeks; and that in the dryest part of this time they could work the mills three hours per day. From this the above computation is taken, whereas, in 1763, I was told this mill could go four hours, as in all ordinary dry times I suppose it can, which sufficiently accounts for the difference of the above results.

5th. Culeam Burn was not before pointed out to me; it has no mill upon it, but all accounts agree that it is at least one-third of Garron Burn at all times; it will be carried along with the Garron Burn into Shawend Burn.

6th. Shawend Burn turns a lint mill near a place called Townhead, about a mile from Dolater bog: this mill is sometimes assisted by a part of the water of Culeam Burn, sometimes not, but exclusive of any such assistance, they can, in the dryest times, by the water of Shawend Burn only, work two hours a day, and if they get the whole of Culeam Burn, the miller supposes they could work four hours. Having gaged their water ways, I find this mill in two hours will spend 27,432 cube feet, exclusive of a constant waste for want of tightness at the dam head, &c.

Besides

Besides the above, by extending an aqueduct trench to the westward from the Kilsyth mills, a number of springs may be intercepted, which form small burns that now run down into the Kelvin; among the number of which are the west burn, Arnig, and Guine Burn, and by like means on the eastward of Redburn, are Acre Burn, Tranock Burn, and several others.

Previously however to any computation, I must take notice, that if 100,000 tons of goods are to be navigated yearly, it is not necessary to suppose that the same proportion thereof is to pass in the dryest time of the whole year as when water is plenty; there are very few navigations but what are sometimes scarce of water; if therefore a navigation be capable of carrying at the rate of 100,000 tons a year in the very dryest times, it is capable of carrying a much greater quantity upon the whole, and that without sensible inconvenience.

I take it for granted that generally the mills upon the burns have a full supply of water, so as to keep them going the whole twenty-four hours for full seven months in the year, and that they are supplied with water to work twelve hours in twenty-four for at least two months more: so that there will not be above three months in a year that they can be at short water, and probably much less than that at the extreme of scarcity.

Let us therefore examine in the first place what our supply will be when the mills are fully supplied with water, which takes in at least seven months in twelve:

	Cube feet.
1st. Achinclough Burn - - - - -	476,496
2d. Redburn in this state supposed equal - - - - -	476,496
3d. The coal-pit level at Wineford - - - - -	25,200
4th. The Garron Burn which turns Kilsyth mill - - - - -	370,388
5th. Culeam Burn, being one-third of the former - - - - -	123,463
6th. Shawend Burn, in this state as good as Garron Burn - - - - -	370,000
The ordinary supply per day - - - - -	1,842,043

Hence it appears, that in the ordinary state of the supply, the Achinclough Burn alone is sufficient, and that they altogether afford as much water, in one day, as will last almost four and a half days, exclusive of the times of great rains and floods, when it is certain as much water may be collected in one day, as will serve the canal fifty.

Secondly.

Secondly. When the burn affords as much water only as to turn the mills twelve hours in twenty-four, then the account will stand thus :

	Cube feet.
1st. Achinclough Burn - - - - -	238,248
2d. Coal-pit level at Wineford - - - - -	25,200
3d. Redburn, supposed now one-third of Achinclough - - - - -	79,416
4th. The Garron Burn - - - - -	196,088
5th. Culeam Burn, one-third of the above - - - - -	65,363
6th. Shawend Burn, equal to Culeam Burn - - - - -	65,363
Common supply in dry weather - - - - -	669,678

Hence it appears, that in common dry weather, the burns afford as much as is wanted for the supply of the canal, and more than half as much to spare, so that three days water is then supplied in two.

Thirdly. We come now to extraordinary droughts :

	Cube feet.
Achinclough Burn, as per former report - - - - -	89,343
The Wineford coal-pit level - - - - -	25,200
Redburn, then supposed the same - - - - -	25,200
Garron Burn, which turns Kilsyth mill - - - - -	65,365
Culeam Burn, one-third of the above - - - - -	21,788
Shawend Burn - - - - -	27,432
Supply in great droughts - - - - -	254,328
Computed expense of water per day - - - - -	415,074
Deficiency per day during great droughts - - - - -	160,746

It is to be remarked, that the above deficiency entirely arises from the allowance for exhalations and foakage, neither of which was necessary to be brought to account in the scheme ; for exclusive of these, there would be a redundancy of 34,614 cube feet per day.—It is however to be noted, that when the mills have but about seven hours water in twenty-four, there will be a full supply for the canal, and that it seldom happens that any drought continues in that degree above seven or eight weeks. It must also be noted, that as the deficiency by exhalations and foakage gradually increases from the

the canal of partition toward the extremities, the supplies for this purpose are not necessary to be conducted to the canal of partition, but may be occasionally taken in by the way: and therefore, that these deficiencies may be supplied by the several burns whose names have been mentioned, but not brought to account for supplying the canal of partition; yet I shall shew, that independently of these burns, and others that may be brought in to the same purpose, the deficiencies above stated may be most certainly and amply supplied as follows:

It is mentioned, page 33, of the former report, that Dolater bog may very easily be put under water by way of reservoir: on this occasion it has been measured, and found to contain upwards of 220 acres English measure. Respecting the twenty acres for other works, we will suppose 200 acres of Dolater bog, by a dam at each end, laid six feet under water; out of this for supplying its own exhalations, we will allow one foot of perpendicular, we can therefore reckon, in time of need, to draw five feet of water from the Dolater reservoir; which will contain at that depth 43,560,000 cube feet, and consequently as much as will supply the aforesaid deficiencies for 270 days, or almost three quarters of a year, or would alone supply the whole quantity for 105 days!

Hence it appears that Dolater bog being turned into a reservoir, would, if necessary, supply the canal during the time of great droughts, without taking any water from the burns; or with their assistance as above, would navigate more than double the quantity of goods required even in the driest seasons.

Nor yet are those the only resources that could be procured if occasion required. In the reservoir way, it is remarkable that the whole face of the country, abounding in hollows, affords frequent opportunities for making them; in particular, a dam not above fifty yards long, where the dam-head of Townhead lint-mill is now fixed, would lay a valley under water four or five fathoms deep, and thereby form a reservoir equal in capacity to that of Dolater, already proposed.

This reservoir would not only be supplied by Shawend Burn, which takes its course through it (and which, though small in dry times, seems to be the best of them all, for supplying reservoirs by downfalls of rain) but will also receive the waters of Garron Burn, Culeam Burn, and Achinclough, all of which may be diverted thereto. The waters of Bishop's Loch and four others in the same neighbourhood, forming altogether a surface of between three and four hundred acres, and which might be pent up from four to six feet higher than at present, may also be brought to Dolater bog. But
without

without insisting further on reservoirs, many more yet of living waters may be applied to our purpose by bringing them from a somewhat greater, though no remarkable distance; in particular, on the south side of the canal, the Loggie water may be intercepted and turned to Dolater bog, from a point where it is as considerable, if not more so, than any of the burns mentioned.—On the north side the water of Glazert, a considerable rivulet, and along with it all the burns west of Kilsyth, viz. West burn, Arnig, and Guine burn, before-mentioned, may be brought so as to fall in with Garron burn and Culeam burn into Shawend burn, and then proceed altogether into the Dolater bog. Furthermore, into the head of the Glazert may not only be turned the water from the spout of Ballagin, and a great number of springs that feed the head of the water of Blain, but even a great part of the river Enrick, (I believe quite as much of it as can be carried to the bog of Bollat) may be brought round the hills upon a sufficient elevation to fall into the head of the Glazert, and be therewith carried to the point of partition: in short, were ten times as much water necessary for the canal as what appears to be, there are the evident means of bringing it, and amassing it without making any strain upon nature: I therefore beg leave once more to repeat a passage of my former report, page 42: “it does not admit of a doubt but that nature has furnished a practicability of bringing as much water to the point of partition as can possibly be wanted, and that by means sufficiently simple and easy,” and again, “so that there is all possible certainty that the canal will be amply supplied from end to end.”

As the Glasgow branch will afford the means of navigating from Glasgow to Port Glasgow, and back again, in neap tides and dry seasons, it will undoubtedly be made use of for that purpose when the river Clyde will not serve; there will therefore be water expended by lockage in this passage of vessels not navigating from sea to sea; but as the branch canal to Glasgow is proposed to be carried on upon a dead level, and without communication with the river Clyde at its upper end, only one lock full will be expended on the passage of each vessel into or from the Clyde.

I am in no condition to judge what quantity of water for lockage may be wanted in this branch of trade; but if as much water were to be used in this branch as will be used in passing from sea to sea, which will navigate four times as many goods upon the branch up and down as upon the transverse passage from sea to sea, there are so many rivers which fall in below the level of the canal of partition, and yet sufficiently above the level of the branch canal, as are sufficient to supply it ten fold, without letting down any water from the canal of partition at all on this account.

In like manner it is to be supposed, that at the Carron end of the canal many cargoes of goods will pass backwards and forwards without crossing from sea to sea, all of which will consume a lock full of water each at their entry and departure from the canal, and yet more if a branch be carried off to Carron shore, as it easily may; but were this trade also equal to the trade across, there are likewise the means of supplying it with water, without letting any down from the canal of partition.

Having now shewn that there is a practicability of producing a most ample supply of water, not only to answer the greatest possible exigencies of trade, but also the greatest possible errors that may be made in computation, it now remains again to shew that we are in equal capacity of repaying the water that shall be necessary to be taken from the rivers that now supply the valuable iron works, &c. upon the Carron, and the valuable mills and iron works that are towards the foot of the Kelvin.

Here I must observe, that though I have shewn how it is possible to bring a vast abundance of water to supply this navigation, yet I have equally shewn how small a quantity really will supply it.—It is sufficient therefore to repay to the full what we really are obliged to take.

Suppose, therefore, the navigation is supplied as first proposed, viz. by the six burns and a reservoir upon Dolater bog; it is manifest that we take nothing from the mills but the value of the six burns, in the dry seasons; for in all others, they are sufficiently supplied without them.

From what has before been stated, it appears, that 415,000 cube feet of water may be expected to supply the canal per day, but that from this what is allowed for soakage, viz. 97,000, ought to be deducted; because, as the soakage returns into the rivers, and will be maintained by means of the reservoir as great in the dryest times as in ordinary, they will get an over proportion when most wanted, and therefore be rather benefitted than hurt by this article: yet, not to be niggardly of a little water, nor to insist upon nice disquisitions where there is no necessity; for the present, we will allow that we are to repay 415,000 cube feet of water whenever the burns will furnish it, and in the dryest seasons whatever they do furnish, which at the least we suppose to be 254,000.—Now this is scarcely three times as much as the Achinlough burn yields in the dryest season singly; a burn, therefore, capable of running three times as much as Achinlough in the dryest seasons, and at other times in proportion, will afford as
much

much water as will repay all the mills both on Carron and Kelvin, and as somewhat about half that quantity is due to one set, and half to the other, it will follow that a burn half as big again as Achinlough will repay the Carron mills, and another of the same size will repay those of Kelvin.

I have mentioned in the former report, page 44, that the river Enrick, at Randeford, may be easily diverted into the Carron, and that it appeared to be there more than double of Achinlough: this I thought sufficient to make good my argument; but had I said four times as big, I believe I should have been nearer the mark: the burn of Ganakin I then but rarely mentioned, but it appeared to be near its fall into Enrick, full as big as the Enrick at Randeford, and having its rise in the Campsie Fells, it cannot be reckoned less than Achinlough at the level at which it may be diverted; hence we cannot reckon these burns together, at less than three times the estimated quantity of water necessary to be repaid to Carron, and therefore by half more than sufficient for the whole re-payment of vessels not passing from sea to sea; and will include the lockage at the Carron end of vessels not passing from sea to sea, were that supposed equal to the lockage of those that are; for it is to be remarked, that let the lockage be increased in whatever degree, the other articles of leakage, exhalations, and soakage, which make two-fifths of the whole stated quantity, will still remain the same, and therefore it is extra lockage only that is to be provided for on these extra accounts; yet to this purpose of extra lockage at the east end, (if we could possibly suppose it needed) not only the Grange burn, but a considerable part of the river Avon, could be brought round to supply the canal; and if this be not enough, as we have already said, the Loggie, the Glazert, the head of the Blain, and even the Enrick, can be brought round to the canal of partition, when their overplus waters may be sent down the rivers either way.

With respect to the re-payment of the Kelvin mills, I am of opinion that the waters that can be turned into the Glazert from the spout of Ballagin and head of the Blain, will of themselves be found sufficient: but not altogether depending on this, it turns out from computation, that as much water can be accumulated in Bishop's Loch, and the four others in that neighbourhood, by penning them to the depth of three feet nine inches only, as is equal to the proposed reservoir of Dolater, and consequently will of themselves repay the Kelvin's proportion of supply to the canal of partition for 210 days or seven months, which is two months more than it ever happens that any of the mills can be the worse on account of the supply taken for the navigation.

Besides

Besides the above, the following is a list of such lochs as might, in like manner, be made use of for treasuring up water, which can be brought into the Kelvin in order to repay the mills, or supply the lower part of the canal on the west side, viz.

Loch Umphrey*,	-	-	-	320 acres, at twelve feet deep, $1\frac{5}{8}$	} times as much as the reservoir of Dolater.
Cockney Loch,	-	-	-	80	
Ditto, as may be made by a dam,	-	-	-	640 at twenty-four feet, 15	
Bardoure Loch,	-	-	-	82 at three feet, $\frac{1}{4}$	
Auchen Loch,	-	-	-	80	
Postel Loch,	-	-	-	80	

Also, a very large hollow in Kilmannan Moor, the land being of small value, that may be converted into a loch, and turned down the Allander.

Also, several small lochs, such as Kilmardonie Loch, Loch Green, St. German's Loch, and others.

Over and above all, we have the river Enrick for our sheet anchor, which being taken up, as already observed, at a sufficient elevation to go over the low flat ground at the point of partition, between the Blain and the Glazert, is of itself sufficient to repay all that is taken for furnishing the navigation; that is, in other words, that the whole navigation might be furnished with water from the Enrick, without taking any thing from any burn or rivulet; that at present feeds either Carron or Kelvin: indeed, this would have been the primary proposition, had not the thing been feasible by more direct and shorter methods; I therefore only mention those things to shew, that in case of any unforeseen occurrence or emergence, we are by no means limited to the supply of the six burns, or unable, in the nature of things, to repay any quantity that it may be needful to take.

It, perhaps, may seem that I have reckoned the Enrick twice, nay, three times over; first, in making use of it for a supply to the navigation; 2dly, in repaying the water borrowed from the Carron; and, 3dly, in repaying the water borrowed from the Kelvin.

But, in answer, I must observe, that if the Enrick be made use of as an immediate supply, it must be brought to the canal of partition; if that be done, it will be of itself a sufficient supply

* This is what it may be made to hold, more than what it now does as a reservoir to Dalmoore mill.

supply, and consequently there will be nothing to repay. If made use of to repay, it will do it to both without interfering; for the water of Enrick will be brought off so much lower down than Randeford, from whence the water is to be taken to Carron, when it has received several considerable rivulets and burns, that there will not only be water to repay what is due to the Kelvin, but water enough left for the mills, if properly applied, and, after all, water to supply another canal by the bog of Bollat, in case that also should be undertaken. But though it may be necessary to show from what abundance of sources water may be drawn for the supply of the canal, yet I do not apprehend it will be necessary to disturb the Enrick at all, except at Randeford, as first proposed. And I am so thoroughly satisfied that there is upon the whole so much more water to be procured, than is sufficient for all purposes, that I cannot hesitate to declare, that the promoters of this undertaking may, for the satisfaction of the country, very safely oblige themselves not to take any water that falls into the heads of Carron or Kelvin in times of scarcity, but what they do actually repay in equal quantity at the same time to the lower parts of the same river.

It may perhaps be doubted, whether there are any certain means of knowing when two streams are equal, so that the parties interested may be satisfied that they have their just equivalent: for the satisfaction of those, it is incumbent on me to say, that water-gages both may and ought to be fixed, so that any person by inspection shall be able to judge at any time of the equality thereof; furthermore, as all overflowings will fall into the rivers, and as the navigation will seldom be able to use all the waters allotted to it, the Carron and Kelvin rivers will of consequence be gainers by this overplus.

The next great point is the places of entry of the canal from the rivers Forth and Clyde, and in this affair it is not to be doubted, but that the greater the depth of water where the entries are, *cæteris paribus*, they are the better.

Conveniencies of trade, are matters that I never undertake to judge of. I am therefore happy that the places of entry have been pointed out by a committee of gentlemen appointed to make due enquiries thereupon; whose opinion, after having been reported before the convention of royal boroughs, has been by them approved, viz.
 “ That the most proper place for the entry from the Firth of Forth will be
 “ somewhere near the mouth of Carron, and on such part of the north-east side of
 “ a farm called the Hewk, as Mr. Smeaton may think proper, after a due con-
 “ sideration.”

Now,

Now, having maturely considered this matter, I cannot hesitate to say, that the most eligible place for the entry on the north-east side of that farm, is that part which points down the sea reach whose general bearing is N. E. by E.: this entry is on many accounts a very proper one; for below this, there is no impediment in going out to sea, save a flat or bar just within the channel of the Carron's mouth at low water; upon which I found five feet water at low water, the 14th day of August last, being the 4th day after the full moon, within which there is a deep called Holemerrie, extending nearly a quarter of a mile, and reaching almost to the place where the entry is proposed; this deep has seven feet more water than the bar, and is therefore a very proper place for vessels to lie in when waiting for the tide.

It is to be observed, that the tide preceding, and that subsequent to the low water, when I founded, were the highest of that spring, which was a very moderate one, but which rose above the said low water full eighteen feet; so that there would be at least twenty-three feet water upon the bar or flat. The spring tides are said sometimes to make twenty-seven feet upon the bar, sometimes to fall short to twenty-one or twenty-two; the neaps make eighteen or nineteen feet upon the bar, and leave them about nine feet at low water; hence it appears, that vessels drawing eight feet water may go in and out at all times of tide in neaps, and that at low water at spring tides they may lie afloat in Holemerrie, till the tide serves, and that vessels drawing four feet water, such as formerly proposed, may go in and out at all times, except at the low water of a very low spring ebb. These are certainly great advantages; but, on the other hand, as there is not sufficient shelter at high water for such vessels as come here to deliver their cargoes, and which are too large to pass the canal, and as I do not apprehend it would be practicable for such vessels as intend to enter the canal to do it with safety when the wind is northerly, and blows hard; it will, therefore, in this case, be necessary either to dig an artificial harbour within land, or to make use of the turn of the river round the Hewk point, and the reach within the same, as a natural harbour, as now it is; the former will be attended with very considerable expenses, and not without inconveniencies, the latter would be attended with the following.

First. The bottom of the river in the Hewk reach, that is, above or up the channel from the proposed place of entry, particularly at a place called the Hewk ford, is $3\frac{1}{2}$ feet higher than the bar; in consequence, in all cases, vessels will have $3\frac{1}{2}$ feet less water in going into the natural harbour, than in coming over the bar; but as there is here no scarcity of water at high water, this consideration, if alone, would be of less consequence. But what seems more material is, that when the wind blows at S.W. or W. which in those climates

climates are the most general of all winds, vessels may and frequently do lose a tide in getting round the Hewk point; on the other hand, when in, an entry from about the Grange Burn foot would at all times be safe, and with about four feet extra flow of tide, certain. In order, therefore, to take every advantage of the situation, I would recommend it to consideration, whether it would not be adviseable to give the canal a double entry; one from the place already proposed, the other from the Grange foot; by this means the cost of a new artificial harbour would be avoided; and all vessels intended for the canal will, at all times, be sure of a safe entry; for such winds as will render the outward mouth difficult, will carry them to the inner mouth; which latter will, at all times, be accessible to goods and vessels from the material harbour.

The extra expense of the canal and interior lock, as well as some addition of leakage, will be objections; but as to the first, the cost will be very far short of making an artificial harbour; and, after what I have said upon the article of supplies, I flatter myself that the latter will totally vanish.

With respect to the west end of the canal, it is certainly very rightly determined by the committee, "that the entry of the canal should not be higher up the Clyde than Dalmoore Burn foot," for higher than this there is no certainty of water for vessels of any greater draft than those specified in my former report; and even to Dalmoore Burn foot, there is not that plenty of water that could be wished. Having carefully founded the Clyde from Dumbarton to the Barns of Clyde, upon the 21st day of August last, being the 5th day after the quadrature, there was at high water upon Dumbuck ford, $7\frac{1}{2}$ feet, and over Erskine Sands above eight feet; all other places betwixt deep water and Dalmoore Burn foot founded above eight feet six inches and nine feet. This tide somewhat exceeded the dead of neap, being the first tide that lifted; but as the ordinary neap tides are reckoned at seven feet six inches upon Dumbuck, and but two feet more at ordinary spring tides, and as the high-water mark at Dumbarton this tide fell short of the ordinary high water of a spring tide by one foot $10\frac{1}{2}$ inches; it is very certain that it could have lifted not above two or three inches at most above the dead of neap; and as I look upon it very practicable to deepen Dumbuck ford one foot, or even $1\frac{1}{2}$ foot, and by contracting the low-water channel of the river, opposite Erskin-house, by proper weirs to run down the loose sands of which it is composed, and constantly maintain at least as good a channel as at Dumbuck, it follows that vessels drawing full eight feet water may, in moderate weather, and at high water, in all ordinary neap tides be able to enter the canal at the foot of Dalmoore burn. The day when the above soundings were taken was remarkably calm and serene, so that it was probable it was unaffected by

by any winds ; and, indeed, the near coincidence of our soundings, with the common estimation of those that use the river, proves it. It must, however, be observed, that the tides of this river are very liable to be altered by the winds, which frequently make them exceed, or fall short, one foot of the ordinary quantity. In these cases, it is possible that vessels drawing eight feet water, coming at dead of neaps, and the wind in an unfavourable quarter, may have to wait a tide or two ; but as S. W. winds make great tides, which are those which ofteneft blow, we may reckon those stoppages to happen but seldom, and they may be placed among the unavoidable chances of navigation dependent on winds, which all vessels out of canals or narrow rivers must be subject to.

It were much to be wished, that the canal could as easily be extended to deep water below Dumbuck ford, as it can at the east end ; but having maturely considered this matter, as desired by the said committee, though I do not doubt of its practicability if expense be unlimited, yet, considering how much more easily the river may be helped in the degree before mentioned, which seems to me likely to answer the purpose, I cannot recommend this part of the work to be undertaken for vessels of eight feet water, but for vessels drawing $9\frac{1}{2}$ feet water, it will be absolutely necessary, and of which I shall, in the estimate, give the best account of I am able.

The proper method of effecting it seems to be, to avoid the fleechy bottom, and Whinstone rock, by making a strong sea bank within high water mark, and to build a wall where the shore is rocky, so as to confine a body of water for the navigation of vessels between that and the main land ; but at Dunglass the neck of Whin rock between the castle and main land must be cut through, so as to afford a navigable passage.

In regard to the general course of the canal, the ground has been carefully examined by boring, by Mr. Mackell, whose abilities in engineery is well known, and who has delivered to me an account of the qualities of the soil for twelve feet deep, in no less than fifty-eight different divisions ; together with many other measures of the hills and hollows through which it has been designed to pass ; also, remarks upon the great of lochs that can be made use of as a supply, or for re-payment of others which are so made use of ; and to whose care and industry this business is much indebted. Having, along with him, carefully reviewed the course of the canal formerly traced out, it does not appear that any very material alterations or deviations from that course are necessary, till we arrive at those places where we must turn off on account of the extensions. In regard to that at the east end, I find it adviseable to bring the canal as before, to or near Bainsford, (just beneath the word Camelton, in fig. 2. plate 4.), where it intersects the
road

road from Falkirk to Carron: in its passage from thence to the Hewk, it may be carried on either side of Kerse-house, the north side is the more direct, according to the dotted line P upon the plan; but as it measures but a quarter of a mile more, to go upon the south side, by Mr. Longmuir's house, and without interfering with the policy, I have made the design and estimate upon that footing, the difference of expense for the $8\frac{1}{2}$ feet canal being £558.

The most material deviation that I have made from the former design, is by taking the Allander passage in preference to the Canny's burn. Having originally given preference to the Allander passage; that part of the tract of the canal from the Allander to Gariscud bridge, was not surveyed, but was laid down by the eye; this alteration of my first intention, was what occasioned the want of an actual survey of that part; for finding, on computation from my notes, after I had left the country, that the expense of cutting the hill from Canny's burn into St. German's Loch, would be greatly short of cutting that by the Allander; this occasioned a correspondent alteration in my design. But upon this last review I find it will be necessary, in passing from the Allander to Canny's burn, to pass through two other hills as troublesome as the former. This would not have been necessary for vessels of the size I first computed upon; because, at all events, I knew I could conduct them down the course of the Kelvin itself to Gariscud bridge; but this, for vessels of the size proposed, would be more troublesome to do than even the impediment we mean to avoid. As, therefore, upon the footing of the present scheme, it will not, according to the best estimate I can make, cost above £1000 more to go by the Allander, than by the Canny's burn passage, and at the same time shorten the distance one quarter of a mile, as well as avoid the policy of Killarmine-house, with a less chance of unforeseen difficulties; on these considerations, I have now drawn and estimated the course of the canal by the Allander passage, at the same time stating the difference, in case the chance of the above saving is thought worthy of attempting.

The next considerable deviation is in order to avoid going through the policy of Grafcuddon, by cutting through a rise of about eighteen feet extra height, which passage was pointed out by Mr. Mackell. This work I estimate to cost £238, which, with some lesser inequalities, may possibly amount to £300. This will, indeed, throw the general course of the canal about three furlongs further round; but, as it will shorten the Glasgow communication by two furlongs, there is, upon the whole, only one furlong extra, the charge of which, for the $8\frac{1}{2}$ feet canal, will be also about £300 more; but, as this will avoid at least £300 extra charge in passing through the piece of water at

Grascuddon, and furthermore avoid the difficulties that may attend a muddy bottom, in going down from the point of deviation to Grascuddon; perhaps, upon the whole, there will be little difference in point of expense. I have, therefore, made the design and estimate according to this deviation.

Upon entering into the detail of this affair in the execution, it must be expected that many deviations may appear eligible; it is, therefore, not to be expected the canal can, at present, be fixed to a point, and I can only say in answer to those that might desire it, that I cannot take upon me to do it, and I think it would be very unadvised in any man so to do, even in works of much less bulk, extent, and expense than this. There must be a degree of latitude in an affair of such great consequence, for second thoughts and improvements.

J. SMEATON.

Austhorpe, 8th October, 1767.

First ESTIMATE for a canal from Forth to Clyde, for vessels drawing eight feet water, and the locks, &c. to contain those of twenty feet wide and sixty feet long, with a branch of the same size to Glasgow.

		£
The canal, for vessels of twenty feet wide, and drawing eight feet water; if made of full width, so as to draw easy, should have a twenty-seven feet bottom, and be $8\frac{1}{2}$ feet depth of water, which will require the canal to be $10\frac{1}{2}$ feet deep at an average; this made with slopes at a medium as three to five, will, at 5 <i>d.</i> per yard cubic, come to £1903. 12 <i>s.</i> 2 <i>d.</i> per mile; but, for even numbers, say £1904. per mile, and the canal, including the Glasgow branch, with its extensions, as per plan, being thirty-seven miles, in the whole, will come to	- - - - -	70,448
This canal will admit of sea-built vessels of the above dimensions to pass in every part; but yet to allow for turning places and other extra widths, allow upon the whole one mile extra,	- - - - -	1,904
The width of the canal at top being sixty-two feet, and the same width being allowed on each side for depositing the earth, and for back-drains, fore-shores, &c. the whole width will be sixty-two yards, which takes $16\frac{3}{8}$ acres per mile, and for thirty-seven miles 603 acres, which, if purchased at a medium at £20, will come to	- - - - -	12,062
Besides what is immediately occupied by the canal, it will be necessary to allow for aqueducts, trenches, reservoirs, and other conveniencies, the value of 100 acres more, which, at the mean price of £20. per acre, is meant to include Dolater bog,	- - - - -	2,000
	Carried forward	86,414
		The

	Brought over,	£ 86,114
The perpendicular height before ascertained, from neap tide high-water mark to the surface of Dolater bog, is 147 feet; but, according to the present scheme, it will not be necessary to enter from the level of the bar, which is reckoned nineteen feet below high-water mark of neap tides; and as it may be adviseable to keep the canal of partition two feet above the level of the surface of the bog, the whole perpendicular will be 168 feet, which at eight feet each lock, makes twenty-one locks upwards, and the same downwards, and will in the whole be forty-two locks; which, for vessels of the dimensions specified, ought to be $20\frac{1}{2}$ feet wide, and seventy-two feet long, which will cost £1000. each,	-	42,000
To an extra double lock, for a double entry at Grange burn foot, with extra expenses in diverting the burn,		2,000
To making an aqueduct bridge over the Grange burn,	-	500
To extra digging in passing a narrow gripe, between two rising grounds, west of Mungull's house,	-	100
To extra digging through the summit of the ground, between Glenfour and Newhall, above Camelton,	-	115
Extra banking across the hollows betwixt Newhall and Bonnie mill, and one small river,	-	600
To an aqueduct bridge in passing Bonnie mill burn,	-	1,500
To extra work in passing Seabegs wood, Trannock burn, Acre burn, and some other hollows, and rises from thence to Castle Cary bridge,	-	400
To an aqueduct bridge for passing the river Bonnie, near Castle Cary bridge, and banking there,	-	1,200
To extra cutting in the canal of partition, so as to make it a fifty feet bottom,	-	1,478
To making two dams, one at each end of Dolater bog, so as to form the whole into a reservoir,	-	300
To defending the dam-heads and banks of the reservoir with stones against the wash of the waves,	-	1,408
To making a sluice for drawing the water from the reservoir into the canal of partition, and over-falls for discharging the water each way,	-	100
To building a dam and other works at Inch Belly bridge, for the passage of the canal there,	-	500
To extra expenses in passing the Loggie at Kirkintulloch,	-	300
To a dam and works at Calder bridge,	-	500
To extra expenses in cutting the hill near New Kilpatrick, in the Allander passage, computed to be thirty-six feet above the bottom of the canal, the digging at 6d., and walling at 5s. per cube yard,	-	9,166
To extra expenses in cutting the hill by the weaver's house, above Grascuddon £258, this, with some other inequalities, may be called	-	300
To extra work in making a jetty to defend the mouth of the canal, from the lodgment of sand and mud, and clearing a passage into Clyde,	-	150
To extra cutting in passing the rising ground opposite Blart hill, and in altering the turnpike road, upon the Glasgow branch,	-	700
	Carried forward	149,731
		To

	Brought over	£ 149,731
To building an aqueduct bridge over the river Kelvin, in order to carry the canal to Glasgow, including other extra expenses in passing that river,	- - -	4,000
To making aqueducts, trenches, with such tunnels and bridges as may be wanted, for bringing the several supplies proposed into the Dolater reservoir,	- - -	500
To six public roads, draw or turning bridges, viz. at the road from Falkirk to Carron and Stirling, Camelton, Inch Belly, Calder, and Brick-house, upon the road from Glasgow to Dumbarton, and one upon the branch canal, where the same road intersects it near Blart hill, at £600. each,	- - - - -	3,600
To ten draw or turning bridges of lesser dimensions, where the lesser roads intersect the canal, at £400.	- - - - -	4,000
To twenty-one carriage bridges, of the draw or turning kind, for communications between the lands, which, with the great and small bridges, make at the rate of one in a mile, at £250.	- - - - -	5,250
To fifteen large tunnels, for communicating the lesser brooks under the canal, at £60. each,	- - - - -	900
To fifty-nine small tunnels, for preserving the present water-courses, making, with the large ones, at the rate of two in a mile, at £20 each,	- - - - -	1,180
To making towing-paths, back drains, gates, towing bridges, &c. at £25. per mile,	- - - - -	925
To bringing the water of Enrick from a little above Randeford into Carron,	- - - - -	150
To bringing the burn of Ballagin, with some springs rising out of the hills to the west of the spout of Ballagin, that now fall into the water of Blain into Kelvin,	- - - - -	100
To making trenches, sluices, &c. for drawing off the water of Bishop's loch, and three others in that neighbourhood, in case it shall be required,	- - - - -	100
To expenses in making weirs to contract the channel at low water for deepening Erskin sand,	- - - - -	1,000
To deepening Dumbuck ford, so as to make eight feet six inches water at common neap tides,	- - - - -	1,000
To temporary damages, unforeseen accidents, impediments, and works, engines, utensils, and surveyors' salaries, supposed at £15. per cent.	- - - - -	25,865
		198,301

N. B. The above is exclusive of all expenses in making harbours, warehouses, quays, and other conveniencies in landing, depositing, and shipping of goods, and of all expenses attending getting an act of parliament, and of all surveys, &c. previous thereto; and for all allowance of interest of monies, and of salaries to the principal engineers and accountants. Nor would I be understood to ascertain any thing as to the value of the lands, the number of acres excepted.

N. B. Whatever waters may be wanted, further than the expense above computed will bring, must be in consequence of such an addition of trade as will very well pay all additional charges.

Second

Second ESTIMATE of the probable expence of making a canal, of ten feet depth of water, from the Hewk farm, at the mouth of Carron upon the Forth, to below Dumbuck ford, upon the river Clyde, with a branch of the same size to Glasgow.

		£
The width of the vessels being twenty feet, as before, the same width of bottom will serve, viz. twenty-seven feet, and the depth of water being ten feet, we may call the whole depth twelve feet, the slopes being three to five, as before, will at 6d. per yard cubic, come to £2757. 6s. 6d. which, for even numbers, call £2758, this for thirty-seven miles will come to		102,046
According to the above dimensions, the mean breadth of the canal at top will be sixty-seven feet, and allowing the same breadth on each side, for the banks, back-drains, and fore-shores, the whole breadth will be sixty-seven yards, this will contain 19. $\frac{4}{5}$ acres Scotch measure, per mile, which, if purchased at a medium at £20 an acre, comes to		14,356
The length, breadth, and rises at the locks, being the same as before, they will be deeper by eighteen inches; which, together with a greater degree of strength necessary, not only on that account, but on account of the greater weight of vessels running against them, will produce a difference of at least £100 in each lock; there will, therefore, be forty-two locks, at £1100 each,		46,200
		162,602
In the foregoing estimate, for 8 $\frac{1}{2}$ feet water, the whole cost is		£198,301
Deduct, viz. cutting		£70,448
Land		12,062
Locks		42,000
Fifteen per cent.		25,865
Total deduct		150,375
Remains for extra works, lands, &c.		47,926
To this add one third for increase in these articles		15,975
The sum will be the supposed expense of the same articles upon the increased plan		63,901
From the Forth to Dalmoore burn foot		£226,503

The ESTIMATE for carrying the canal from Dalmoore burn foot, to below Dumbuck ford, being four miles, is as follows:

	£
To making an aqueduct bridge over Dalmoore burn	667
To making the canal within land three-quarters of a mile below the foot of Dalmoore burn ; that is, cutting and land, at the price mentioned of the first and second article	2,369
To raising a strong bank within the tide's marks, and thereby inclosing a space to be used as a canal ; this, at sixpence per yard, is £3,300 per mile, and for one mile and three- quarters	5,775
To defending the same towards the Clyde, with stones ; these at two shillings per ton, come to £704 per mile, and for one mile and three-quarters	1,232
To building an aisler wall, where the Whinstone rock interferes, upon a sloping shore, being about half a mile in length ; the solid being computed at five shillings per cube yard, will come to	1,173
To aisler facing for ditto, at eight pence per yard	1,320
To forming a slope of earth within the same, at sixpence per yard, cubic	352
To cutting the neck of Whinstone rock, behind the castle of Dunglass, so as to make a passage twenty-four feet wide, containing 64,000 cube yards, at five shillings	1,600
To one mile of cut below Dunglass, in order to clear the ford, and get into deep water ; the cutting and land as per first and second article	3,146
This being done in the tides way, we may add for drainage of water, and other extra ex- penses	400
From Dalmoore burn foot, to below Dumbuck head	18,034
From the Forth to Dalmoore burn foot	226,503
The whole work being attended with greater hazard of rocks, mud, and many other difficulties, I think it necessary to allow twenty per cent. for contingent expenses upon the whole estimate	48,907
	£293,444

N. B. Exceptions as before.

Third ESTIMATE of the expence of a canal of seven feet depth of water, from the Hewk farm, at the mouth of Carron to the foot of Dalmoore burn, upon the Clyde, with a branch of the same dimensions, to Glasgow :

As I suppose a canal of seven feet deep, vessels of about eighteen feet will be the ordinary size, a twenty-four feet bottom will be sufficient, and the mean depth being supposed nine feet, this with battens or slopes in the proportion of three to five at a medium, will, at 4 <i>d.</i> per yard, cubic, come to £1,144 per mile, and this for thirty-seven miles, including the Glasgow branch and all extensions as per plan, comes to	42,328
To allow for passing places, turning places, &c. I allow the value of one mile extra	1,144
The width of the canal at top being fifty-four feet, and the same width being allowed on each side for depositing the earth, back drains, fore shores, and other occasions, this will make a breadth of fifty-four yards, which is $15\frac{6}{10}$ Scots acres per mile, and for thirty-seven miles, $577\frac{2}{10}$ acres, which, supposing the purchase made at a medium price of £20, will come to	11,544
Besides what is immediately occupied by the canal, it will be necessary to allow for aqueducts, trenches, reservoirs, and other conveniences, the value of £100 acres more, which at the mean price of £20 per acre, is meant to include Dolater bog	2,000
The perpendicular height of 147 feet before ascertained from neap tide high-water mark, to the surface of Dolater bog, must be added according to the present scheme, the height of the said neap tide high water above the level of the bar, viz. nineteen feet. And as it may be adviseable to keep the water in the canal of partition two feet above the level of the surface of the bog, the whole perpendicular will now become 168 feet, which, at eight feet each lock, makes twenty-one locks upwards, and the same downwards, that is, in the whole forty-two locks, which, if made $20\frac{1}{2}$ feet wide, and seventy-two feet long, to hold vessels of twenty feet wide, and sixty feet long, will cost £900 each	37,800
To an extra double lock for a double entry, at Grange burn foot, with extra expenses in diverting the burn	1,800
To making an aqueduct bridge over Grange burn	400
To extra digging in passing a narrow gripe between two rising grounds, west of Mungull's house	100
To extra digging through the summit of the ground between Glenfour and New Hall, above Camelton	100
To extra banking across seven hollows betwixt New Hall and Bonnie mill, and one small rise	600
To an aqueduct bridge in passing Bonnie mill burn	1,250
To extra work in passing Seabeg's Wood, Trannock burn, Acre burn, and some other hollows and rises from thence to Castle Cary bridge	400
Carried forward	98,466
	To

	Brought over	£ 98,466
To an aqueduct bridge for passing the river Bonnie, near Castle Cary bridge, and extra banking there,	-	1,000
To extra cutting in the canal of partition, so as to make it a fifty foot bottom,	-	1,478
To defending the dam-heads and banks of the reservoir with stones against the wash of the waves,	-	300
To making two dams, one at each end of Dolater bog, so as to form the whole into a reservoir,	-	1,408
To making a sluice for drawing the water from the reservoir into the canal of partition, and over-falls for discharging the water each way,	-	100
To building a dam and other works at Inch Belly bridge, for the passage of the canal there,	-	500
To extra expenses in passing the river Loggie at Kirkintulloch,	-	300
To a dam and works at Calder bridge,	-	500
To extra expenses in cutting the hill in the Allander passage, near New Kilpatrick, computed to be thirty-five feet above the bottom of the canal, the digging being estimated at 6d., and the walling at 5s. per cube yard,	-	8,166
To extra expenses in cutting the hill at the weaver's house, above Grascuddon, with some other inequalities there,	-	250
To extra work in making a jetty, in order to defend the mouth of the canal from the lodgment of sand, and clearing a passage into Clyde,	-	150
To extra cutting in passing the rising ground opposite Blart hill, and in altering the turnpike road upon the Glasgow branch,	-	600
To building an aqueduct bridge over the river Kelvin, in order to carry the canal to Glasgow, including other expenses in passing that place,	-	3,500
To making aqueducts and trenches, with such tunnels and bridges as may be wanted, for bringing the several supplies proposed, into the Dolater reservoir,	-	500
To six public road draw bridges, or turning bridges, viz. that at the road from Falkirk to Carron and Stirling, at Camelton, Inch Belly bridge, Calder bridge, and Brick-house, upon the road from Glasgow to Dumbarton; also one upon the branch canal, where the same road intersects it near Blart hill, at £600. each,	-	3,600
To ten draw, or turning bridges, of lesser dimensions, where the lesser roads intersect the canal, at £400.	-	4,000
To twenty-one carriage bridges for communication between the lands,	-	5,250
To fifteen large tunnels for communicating the lesser brooks under the canal, at £60. each,	-	900
To fifty-nine small tunnels for preserving present water-courses, making, with the large ones, at the rate of two in a mile, at £15. each,	-	885
To making towing-paths, back-drains, gates, towing bridges, &c. at £20. per mile,	-	740
To bringing the water of Enrick from a little above Randeford into Carron,	-	150
To bringing the burn of Ballagin, with some springs rising out of the hills to the north-west of the spout of Ballagin, that now fall into the water of Blain into Kelvin,	-	100
	Carried forward	133,843
		To

	Brought over	£ 133,843
To making trenches, sluices, &c. for drawing off the water of Bishop's loch, and three others in that neighbourhood, in case they should be wanted,	- - -	100
To temporary damages, unforeseen accidents, impediments, and works, engines, utensils, and surveyors' salaries, supposed at £10 per cent.	- - -	13,394
N. B. Exceptions as before,	- - -	<u>147,337</u>

J. SMEATON.

Austhorpe, 8th October, 1767.

The most material point, as it occurs to me, is concerning the place of entry at the Canon end of the canal, and the question seems not whether the entry ought to be at the Hawk farm, or further up the river, at or near the Canon establishment: but whether an entry as or near the Canon establishment alone, will not be preferable to an entry at each of those places.

It has been given out (and I find Mr. Yeoman touches upon it), that the place of entry were not of my choosing; and as they differ from the place pointed out in the plan contained in my first report, that this deviation is contrary to my own opinion, and wrong in itself.

In order to clear my way through the whole of this question, I beg leave to premise that when I made my first report, the two great difficulties that were apprehended were money and water; of the latter I found a difficulty, but of the former I had great reason to be apprehensive there would be no superabundance; and as the loss of vessels, &c. of the canal, and species of navigation, were entirely left to my choice by the Board of trustees, who then did the honour to employ me, my endeavour was to produce a scheme which was likely to answer the end proposed, viz. a general communication between the two seas, and which as such could be executed at the smallest expense.

In this view of a general communication between the two seas, it seemed to me a time and now, that it should be of a sufficient size to carry vessels as could freely

A REVIEW of several matters relative to the Forth and Clyde navigation as now settled by act of parliament, with some observations on the reports of Messrs. BRINDLEY, YEOMAN, and GOLBURNE, by JOHN SMEATON, civil engineer, and F. R. S.

I NOW sit down, at the recommendation of the committee of the Forth and Clyde navigation, to consider the reports of Messrs. Brindley, Yeoman, and Golburne, and, (as desired), to make such observations thereon and answers thereto, as to me shall seem proper. I shall, therefore, endeavour to acquit myself of this business, not altogether by pursuing the questions and answers in the order in which they have been produced, but by endeavouring to bring the main things as much as possible into view.

The most material point, as it occurs to me, is concerning the place of entry at the Carron end of the canal; and the question seems not whether the entry ought to be at the Hewk farm, or further up the river, at or near the Carron establishments: but whether an entry at or near the Carron establishments alone, will not be preferable to an entry at each of those places.

It has been given out, (and I find Mr. Yeoman touches upon it), that the places of entry were not of my choosing; and as they differ from the places pointed out in the plan contained in my first report, that this deviation is contrary to my own opinion, and wrong in itself.

In order to clear my way through the whole of this question, I beg leave to premise, that when I made my first report, the two great difficulties that were apprehended were money and water; of the latter I found a sufficiency, but of the former I had great reason to be apprehensive there would be no superabundance; and as the sort of vessels, size of the canal, and species of navigation, were entirely left to my choice by the Board of trustees, who then did me the honour to employ me, my endeavour was to produce a scheme which was likely to answer the end proposed, viz. a general communication between the two seas, and which as such could be executed at the smallest expense.

In this view of a general communication between the two seas, it seemed to me a *sine quâ non*, that it should be of a sufficient size to carry such vessels as could freely and

and securely navigate the two Firths, whereon the two ends of the canal must terminate; for by this property every port on each of the Firths will in a manner become a harbour to the canal, and partake of the benefit thereof, in proportion to their more or less advantageous situation: whereas a canal of a less size, capable of admitting such vessels only as would navigate the canal, without being capable of navigating the two Firths, could never be considered as a general communication between the two seas, but only as a particular communication between two places, one at each end of the canal, and each communicating with the respective seas; and which places would thereby reap, in a manner, the whole benefit; and more especially so, if the points of termination were drawn into such shallow water, that no other port or place could avail itself of the passage without the use of mean or intermediate vessels to carry goods from the principal sea-ports, where large vessels could be received to the respective entries of the canal, which double transshipping would lay such a weight upon the out-ports, as would in effect become an entire monopoly of carriage between the two places of termination.

As I neither was at that time, nor profess now to be, so far master of the general art of constructing vessels for navigation, as to assign the measures most proper for each particular service, and finding the artists themselves in these branches to differ in their opinions, those who have been chiefly in the practice of building flat vessels for shallow water, attributing properties thereto which are by no means allowed by those who are in the habit of building sharper vessels for deeper water; and being willing to found myself upon secure principles, I took the ga boats or galberts of the river Clyde for my model: knowing that the daily practice of these vessels was to carry goods between port Glasgow and Greenock to Glasgow, and I was informed they occasionally went to much more distant places upon the Clyde, and even to Ireland; knowing also from a former acquaintance with the river Clyde, the difficulty of getting up these vessels to Glasgow in dry seasons and short tides: I took for granted that these galberts were constructed upon as flat a model as would answer the purposes of the navigation in the open Firth; and as I found they drew at a medium about four or $4\frac{1}{2}$ feet water, I concluded that a canal of five feet depth of water would give such latitude in point of construction, that my principal view could not miss of being completely answered, that of a free, open, and general navigation, between every port on the Firth of Clyde, to every port on the Firth of Forth.

It is true I know of no such vessel on the Firth of Forth; the flatness of the river Clyde, some miles below Glasgow, having produced the necessity of using
galberts

galberts on that Firth; yet, by parity of reason, I supposed them as capable of navigating one Firth as the other.

Having thus found myself in possession of a vessel, which, though the smallest that would effectually answer my view of a general communication, was yet considerably more bulky than those commonly used in the artificial navigations in England; and as the bulk, weight, and expense of those works must increase in proportion to the weight of the vessels that are to navigate through them, this occasioned me to conclude that these were the largest size that would be convenient for an artificial navigation. See first report, page 40, and second report, page 73.

The twofold view of a general communication, and at the least possible expense, determined me likewise with respect to the places of entry. I was not insensible at that time that if the places were so chosen, that the vessels could enter at all times of tide, it would be preferable to their entering at high-water only, at neap tides; but the extensions necessary to produce this, seemed to me likely so much to swell the expense, that I laid aside every thought of that kind, and contented myself with proposing such places as afforded a secure entry at the high-water of neap tides. This produced the proposition of an entry a little above Abbotshaugh, at the Carron end; for though the tide navigation might have been continued a little further up, yet the ground for a departure appeared to me far less proper. With respect to the entry at Barns of Clyde, that could not properly be carried higher on account of a shoal just above, where the galberts are stopped at short tides; and though the city of Glasgow had at that time an act of parliament which authorised them to deepen the river, which might have enabled the entry to have been made nearer Glasgow, in case that had been performed; yet, as the magistrates of that city had laid aside their prosecution of that work for some years, after it had been put in hand under my direction, I could not think it right to advise my employers to build any part of their scheme upon one which another set of gentlemen had it in their power to execute, or not, as they thought proper.

These were the general views and ideas upon which my first plan and report were built, which were delivered to the honorable Board of trustees for fisheries and manufactures in Scotland, in March, 1764; it now comes in course to shew my reasons for the deviations from the above plan, as per second plan delivered in the month of October, 1767.

But

But first I must premise, that in whatever character my brethren may be ambitious of acting, I leave that to them; for my own part, I shall take this opportunity, as I find gentlemen apt to mistake the character in which I am desirous of appearing, to declare that I do not act in consequence of any public authority or commission, to enquire, determine, and declare what is best for the public, or what in its consequences will assuredly promote its good. I should indeed be very sorry to have so great a weight laid upon my shoulders, which neither my studies nor inclinations have qualified me to undertake. I consider myself in no other light than as a private artist who works for hire for those who are pleased to employ me, and those whom I can conveniently and consistently serve. They who send for me to take my advice upon any scheme, I consider as my paymasters; from them I receive my propositions of what they are desirous of effecting; work with rule and compass, pen, ink, and paper, and figures, and give them my best advice thereupon. If the proposition be of a public nature, and such as involves the interest of others, I endeavour to deliver myself with all the plainness and perspicuity I am able, that those who may have an interest of a contrary kind may have an opportunity of declaring and defending themselves. I do not look upon the report of an engineer to be a law, at least not my own. As a proposition, every one has a right to object to it, and to endeavour to prevent its passing into a law, or to oppose its execution in such a way as may be detrimental to others: had, therefore, Messrs. Brindley, Yeoman, and Golburne been sent for in consequence of my second report, published in 1767, in order to have examined the matter thereof, and to have enabled those who might think themselves concerned to oppose the proposition, nobody could have objected to such a procedure; but after the proposition has been suffered to pass into a law, and thereby tacitly assented to, to send for engineers to determine whether the law itself be rightly founded, and to prevent the execution till that be determined, is indeed to me a very extraordinary evolution, and a sort of proceeding which, as I think, every well-wisher to the success of the scheme should set his face against. Had the matters objected to been different in the act from the scheme, or had the execution of the act differed from the act itself, there had been some colour for this interposition; but, if not, and if it was as well known that the Hewk farm belonged to Sir Lawrence Dundas, in October, 1767, as that the estate of Abbotshaugh belongs to Messrs. Garbett and Co. in 1768, those manœuvres cannot now be looked upon other than an unseasonable interposition to stop the progress of the work.

Respecting the two schemes, I have no hesitation in declaring that my scheme for a general communication between the two seas is contained in my first report, that is, with such corrections as the difference of circumstances that have arisen since my first report was

was drawn up, and better information might suggest; and that the enlargements upon my first plan and report were propositions given me by my employers, and I should be surprized, if this should be matter of news to any one concerned, since I have fully declared the same in my second report, to which I refer; nor could I possibly see the matter in any other light, since the revival of my first plan was undertaken in consequence of a compromise between the contending parties in parliament at the close of the preceding session; one of which articles was, a branch to Glasgow of the same dimensions as the main canal, which, 'tis very probable, I might never have advised as a thing to be undertaken by the proprietors of the main work. The places of entry were also pointed out to me by the report of the committee of royal boroughs, which I have stated in my second report, pages 85 and 87, a copy of which I received from Mr. Chalmers, who also furnished me with the greatest part of the data, as stated in my second report, upon which I proceeded; but I beg leave to say it does not follow, that because I did not form the propositions for enlarging my first scheme, I did not approve of them; the material question, I think, is not who formed the propositions, but whether the matter therein contained be right or wrong.

In regard to the increase of depth of water beyond my first proposition, I take it as a self-evident truth, that every increase of depth must be an increase of advantage to trade; but as trade is not my profession, I neither do, nor ever did, take upon me to determine whether any given increase of depth would be attended with an advantage equal to the increase of expense, and also length of time attending the execution: this I must leave to men of trade to determine, 'tis sufficient for me if I can compute what the difference of expense will be. It was, therefore, given me as a proposition to compute the expense of a canal of seven feet, eight feet and a half, and ten feet deep, in order that those whom it concerned might make their choice.

Respecting the extensions, it is impossible for me now to say what my ideas of the necessity thereof might have been, had not this part of the work been undertaken and prepared for me before my arrival, by the convention of royal boroughs. That "the greater the depth of water where the entries are made, *cæteris paribus*, they are the better," I could easily see, without the help of the committee of royal boroughs; but in what degree trade would be benefited by a given difference of depth of water at the entries; or to say what difference of depth is to trade worth what sum of money; how far the cap ought or ought not to be put off to certain very respectable bodies of men, or the line drawn aside from the more general convenience, are matters that might have puzzled me, had they been left naked to my determination. I there-
fore

fore thought myself very happy, that this part of my task had been brought to a point by so respectable a body of men, who, if I understand the affair, are a body incorporated by act of parliament, and have the sole power of regulating public matters of trade throughout Scotland, and whose authority therefore in this kind of matters I had reason to think so much better than my own. I can therefore only now declare the reasons that induced me to acquiesce in the opinions of these gentlemen respecting the places of entry; which, if I could not have done, I should certainly have thought it my duty to my employers to have declared.

In the first place, I found the number of vessels so much encreased at Carron, beyond what I had observed at Carron shore, when I was upon my survey in August, 1763, owing not only to the increase of trade occasioned by an augmentation of iron works there, but more especially by the establishment of the Carron Ship Company since that time; that had my first idea of a five feet canal, to be done at the least possible expense, been adhered to, I should certainly, on this review, have advised the entry to have been made below all the Carron establishments, in order that such vessels as wanted to pass the canal, independent thereof, might have room to go quietly by them. This, I say, must have been the case had the five feet canal been adhered to; but as the proposition now was for a canal of at least seven feet, and of a depth of $8\frac{1}{2}$ feet, at a medium, as a much greater quantity, and bulk of vessels must be expected in consequence of its admitting those of a sea construction, I did not, nor do I now think, that the new cuts through which the river is turned, which begin just below the elbow where the grounds of Abbotshaugh terminate, of sufficient width to afford a convenient resting place for such kind and sort of vessels as were now intended to navigate the canal: add to this, that but a little way below the termination of these cuts, there is the most remarkable shoal or ford upon the river commonly called Jemmy Reay's Ford, upon which, at high water at a neap tide, according to all accounts there is not above eight feet water, and in low neaps short of that. As therefore the vessels proposed could not sometimes, even at high water, pass this shoal, the great and uncertain expense of lowering thereof, so as to make it certain and convenient for vessels requiring any of the depths of water contained in the new proposition; and I may add, the not having a perfect certainty of its remaining so, even after cleared; made it seem to me very advisable, in a work intended for a general communication, to avoid all uncertainty of expedients, and to carry the Canal below Reay's Ford. But, supposing that done, we cannot go above a quarter of a mile before we come to one of the most remarkable loops in the whole river, which either must be cut, or the navigation would remain inconvenient; and as my idea of the facility of cutting those loops, so as to make them suitable to the river,

did

did not, nor does now, happen perfectly to correspond with those of my brethren, who have since been consulted, I was of opinion that the canal could be continued superficially upon the banks of the river at far less expense than this neck could be cut; and with this further, and very material advantage, that there is at least four feet more water to Grange burn foot than if dropped into the straight reach below Reay's Ford; this in consequence carried me down to Grange burn foot, to the place where the interior entry is now proposed. And as I neither did, nor do approve of making a cut for the river Carron across the Hewk farm, in order to make the entry of the canal perfectly convenient; and upon a supposition that money was not wanting, it did and does to me seem advisable to extend the canal across the Hewk farm to Holmerrie, because here vessels of seven, or even eight feet water, instead of being confined to half an hour at the high water of a neap tide, may go in at a neap tide low water, which, in my opinion, is not only a great advantage, but I take the liberty of asserting once more the outward entry will be attended with this further convenience, that a vessel which can go into the outward reach of the Carron, may enter the canal at the exterior, or if not there, at the interior entry: for these reasons I concurred with the committee of royal boroughs, that if general convenience be the object, and not saving money, which is a language not spoken of to me till lately, the canal ought to be extended to the Hewk farm.

It is very certain that if the proprietors will abate of the conveniencies of the canal, the expense may be considerably shortened: but I am not convinced that the expense will, upon the whole, be shortened by executing the alterations of the river Carron proposed by the three gentlemen, whose reports I have now before me.

I should be much surprised if any of the proprietors who have attended the business of the canal, should be uninformed that it would save expenses by beginning the canal higher up the river than the Hewk farm; but it is certain the conveniencies are far from equal, as is apparent by the gentlemen's taking so much pains to form expedients to remove even in part, the natural difficulties which make the difference; and as to that part which they cannot remove, they tell you, that you will save money: they cannot say, they do not say, that it is as good to enter where you can go in at the high water of a neap tide only, as it is to enter where you can go in at the low water of a neap tide; but they tell you, that if you will give up this advantage, you will save some extent of canal, (made upon the superficies of the ground, where it is most easy;) and you will save the locks whereby you would be enabled to go down into deep water: why truly we knew all this, without Mr. Brindley, Mr. Yeoman, and Mr. Golburne. How much

much of convenience to trade, is worth how much money, I have already said, is not in my power to estimate; 'tis enough if I can make an estimate of the cost of what, I beg leave still to say, is the most complete; whether this be, or be not worth the money I leave to men of trade to judge. For my own part I choose to build my designs upon sure grounds, whenever sure grounds are to be had; 'tis time enough to apply to expedients when we can do no other; that what is proposed are but expedients the gentlemen themselves, who propose them, apprehend; because they desire the works may be stopped till it is seen whether they succeed or not.

In regard to the Clyde, I think it stands confessed that in its present state an entry suitable to a canal of even seven feet constant water cannot be made materially higher than Dalmoore burn foot; and even thither, there is not that ample sufficiency of water which is to be wished; could it have been extended from Dalmoore burn foot, into as good water as is at Hewk farm, at an equal expense to the probable difference between beginning at Abbotshaugh and Hewk farm, I should not hesitate to advise it, if the money could be procured to do it. This, I say, is the case according to the state in which I found the river Clyde in the years 1763 and 1767, and to have built any part of a scheme of this still greater extent, upon what the Magistrates of Glasgow had it in their power to do, or not, at their pleasure, and which they might or might not be able to do, would, in my opinion, have been very indiscreet in me to have recommended. Mr. Golburne had not been upon the Clyde at that time; and if he had, it would have been no demonstration to me that making a channel for vessels drawing six feet water was making seven feet water, since the galbert men could have told him that if they have an inch to spare they never stick fast upon a shoal: be this as it may, if he can, as he says in his report, bring up vessels drawing six feet water to the Broomie law at all tides, (and as is said for him, without lock or dam,) for the sum of £7000, he will do a thing remarkable in itself, and a good thing for the city of Glasgow, and in which I wish him and the city of Glasgow much success: when that is done, the branch canal may be shortened several miles, by dropping into the river Clyde just below Blart hill: but as I like to work upon safe grounds when I can, Mr. Golburne must excuse me if I cannot recommend to the proprietors to give up their entry near Dalmoore burn foot, or stop their proceedings in joining the two seas, until he has brought his scheme to bear. Having now shewn the reasons why my plans have been what they are, and in particular why I did not dissent from the committee of royal boroughs in regard to the places of entry; and in the course thereof why I think a compound entry at Hewk farm, at Grange burn foot, and one nearer the Carron wharfs, preferable to a single

entry near the Carron wharfs only; I shall now proceed to make some observations upon the most material points wherein I differ in opinion from my brethren.

1st, 2d, and 3d. With respect to the answers to the 1st, 2d, and 3d queries, I do not find that Messrs. Brindley and Yeoman have controverted any material point by me laid down; I have only to observe, that though they both in effect allow that they have not examined the sources of water with that exactness that I have done, yet they admit that 100,000 tons of merchandize may be carried annually from sea to sea each way, whereas the quantity I have estimated is no more than two-thirds of 100,000 each way. See 2d report, page 74. I do not mean however to contradict them.

4th. Mr. Brindley recommends a canal of four feet deep, and vessels drawing three feet water to be seven feet wide, and seventy feet long: this would be a very effectual way of securing the use of the canal to the two terminations; no port but that of Carron could have the least chance, for since this kind of vessels could scarcely venture out of the narrow cuts, not even below Jemmy Reay's ford, in a windy day; the large vessels that now come to the Green brae, (that is, the natural harbour, constituted in the reach within the Hewk point,) would be obliged to employ a mean or middle sort of vessel to carry the goods from the ship to the entry of the canal, and the same at the other end thereof: as to the ports of Leith, Borrowstonness, and many others upon the Firth of Forth, together with Greenock, Port Glasgow, and many others upon the Firth of Clyde, they would have no chance, even Glasgow would stand but a bad chance without a side cut of equal dimensions, or the main canal itself terminated there.

In this case Mr. Brindley would have done well to have recommended the sort of restraints that he would advise, to prevent monopolies and impositions at wharfs and warehouses, since no body but those at the terminations could have any business there. Mr. Yeoman agrees in thinking the seven feet canal to be most proper, and Mr. Brindley, that it should not be exceeded.

N. B. As no difficulty is too great for Mr. Brindley, I should be glad to see how he would stow a fire engine cylinder cast at Carron, of $6\frac{1}{2}$ feet diameter, in one of his seven feet boats, so as to prevent its breaking the back of the boat, or upsetting.

5th, 6th, 7th, 8th, 13th, and 14th. There is no doubt but that the cutting of the neck of land, referred to in the 5th question, will be a very great improvement to the navigation of the river Carron, up to Carron shore; because I look upon it that vessels find far more embarrassment and difficulty in getting round this loop, than in all the rest: and

and I am also of opinion, that this may be done without prejudice to the canal, as now going on according to act of parliament, provided proper caution is used, and the undertakers laid under proper restrictions; and it is a work that I am told Sir Lawrence Dundas did propose to have done at his own charge; but with respect to the cutting of the point of land from Grange burn foot to Holemerrie, or taking the two necks together in one sweep from above the upper Salmon Zair to Holemerrie, I cannot by any means agree with my brethren in opinion; but that instead of making an excellent harbour of two miles, they will entirely spoil a good harbour, which is now furnished by nature ready made.

I believe it may be laid down for a general rule, that all small harbours have some inconveniencies, (small I call that at Green brae in comparison of Milford Haven), for the same means that render them more secure for vessels when in, in general render them less accessible, especially by some particular winds.

With respect to vessels intending to enter the canal, there is no difficulty; they can always enter by either the exterior or interior mouth of the canal, or one of them, whenever they can get up the sea reach, or mouth of the river Carron, as before taken notice of. I must observe that the sea reach is wide enough for vessels to turn to windward, but that in the reach next above, leading to the Hewk point, the channel is too narrow for large vessels to do it, and troublesome for small ones, unless we except at or near high water spring tides. It will therefore happen, that when the wind blows right down this reach, which bears S. S. E. and N. N. W. or indeed within six points of the compass, that there will be a difficulty in getting vessels, especially large ones, up this reach; but then it is to be observed that this reach, lying nearly parallel to the Firth of Forth, nearly the same winds that hinder them sailing up this reach will also be against them sailing up the Forth to Carron mouth; however, as there is ample room in the Firth of Forth for vessels to turn to windward, I do admit that it may happen that vessels may get into the Carron mouth, when they cannot get up this reach; but in all these cases, as the wind will blow over land, this reach will be a place of safety for such vessels to lie in till the wind changes favourably; and indeed there is no occasion for their lying here, unless it blows hard against them, because the length of this reach is not so great, but that they may one tide of flood warp themselves in round the Hewk point, where they meet a safe harbour, and in every respect, except the circumstances above mentioned, an excellent harbour, as is already found by the large vessels that frequent it, and deliver their cargoes at the Green brae, a harbour capable of taking vessels at spring tides of five or six hundred tons, and of three or four hundred tons, (according as they are built), at neap tides. The author of a tract now before me, seems to have been fully
sensible

sensible of the importance and excellence of this harbour; when speaking of the river Carron he says, “ within the mouth of the river there is a most capacious station for
 “ ships of any burthen, of about half a mile in length, having from twenty-two to
 “ twenty-four feet water in spring tides, and from sixteen to eighteen in neap tides.

“ Further up the river, (near the place where the canal is intended to come in, and
 “ where the Carron company have built wharfs or quays for the export of their iron and
 “ other manufactures), the harbour has been greatly improved by cutting one large
 “ loop, and there is another now cutting in the river, (both at their own expense),
 “ which will make twelve feet water in spring tides, and eight feet in neap tides.

“ The harbour of the river Carron is capable of containing 1000 sail of ships, and
 “ the boats using the canal may sail to any one of them, whether they be at the entrance
 “ of the canal, (where ships using the coasting trade do now come up), or at the
 “ mouth of the river at Green brae, (where ships, drawing from twenty to twenty-four
 “ feet water, of 500 or 600 tons or upwards may lie), and this without any expense of
 “ lock dues, &c. as the river is a free navigation.”

Who was the author of this tract I know not, but when I was upon the view of the river Carron, in August, 1767, it was put into my hands by Mr. Gascoigne, as a thing whose truth was not to be questioned: it is entitled, “ A short description of the harbours of Borrowstonness and Carron, with a comparative view of their importance with regard to the communication between the east and west seas.” Moved with the truths above referred to, I was very unwilling to propose any thing to the detriment of this most useful and excellent harbour, and being at the same time as great an enemy to monopolies and impositions at wharfs and warehouses, as any of my brethren, I was willing to take the advantage of this harbour, in such manner, that a great part if not the greatest part of all the goods that will require transshipping in the Carron, may be done without the use of wharfs and warehouses at all. This part of the river, which alone can be properly called the harbour of Carron, is of a considerable width, the bottom every where a soft mud, easy for vessels of all kinds to lie upon, and is divided into two channels by a bank also of soft mud, upon which there is fourteen feet water at spring and nine at neap tides, according to soundings marked thereon in a plan annexed to the tract above mentioned; the two channels are on each side near the shore, and are rather capacious than confined: it is not easy to say how wide they are, for as the whole bottom is soft mud, which in course forms itself upon very gentle slopes, a very little difference in the flow or ebb of the tide makes a considerable difference in the width; however,

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as the whole bank is covered at, or soon after, the first quarter's flood, the river I suppose then to be at least 600 feet wide; what the precise width is, I cannot at present say, having not yet got any plan sufficiently exact to determine it; this, however, I know from inspection, that it is a great width, and apparently the widest part of the river.

The depth of the canal, as it is settled by act of parliament, and the width thereof, and of the locks as intended in consequence, are capable of carrying vessels built galbert fashion, (and capable, in like manner, of navigating the two Firths) of 100 tons burthen; such sea vessels, therefore, as cannot pass the canal, but want to tranship in Carron water, will lie in one of the channels, where they now do, and where one of these large galberts may lie alongside of them; or if need be, one on each side at a time, from whence the cargoes can be transhipped from vessel to vessel, without the use of wharfs and warehouses, while the other channel and bank are left clear for the passage of vessels to the canal, or to Carron shore: nor can vessels for the canal be in the way of those going up the river; for, besides room for several that will be made in the tail of the canal, exclusive of the river, whenever they are opposed by wind at the inner entry, they have a fair wind at the exterior: nor can there be any objection to this method of transhipping, since, in a manner, the whole of the coals of Newcastle and Sunderland are shipped in this way, and unshipped at London; and not only coals, but the India, and, in general, almost all the ships of large burthens, that use that port. I beg leave further to observe, whenever vessels happen to be stopped from going round the Hewk point into the harbour, that they are at safe mooring in the Hewk reach, where they need not lose time, if this way of transhipping is used, as the galberts can go to them there, and make their entry good at the Hewk lock.

Let us now examine what my brethren would give us in lieu of these advantages. That the making a straight or curved cut, as they have proposed, will enable vessels to go up to Carron with the same wind that enables them to enter the Carron's mouth, or otherwise to be towed up by horses, I can in part grant; and that this will be an advantage to the Carron wharfs and warehouses, I can grant also; but it happens here, as in many other cases, that while one thing is mended, another is made worse; and it seems to me, that by the gaining this one advantage, of a more general entry, we shall lose all the rest. I wish my brethren had been kind enough to tell us, how wide at bottom and top they proposed to make this cut; because I must tell them, unless it is of very different dimensions from what is already executed as a specimen in the last new cut, I shall not like their project any better than they like mine. Mr. Golburne, who seems

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to be the oracle in this part of the work, says, "and by confining the new river on each side, the current will act upon the bottom, and grind it down to a proper depth." This proper depth he no where tells us; however, it is plain enough he does not intend it to be very wide, and, indeed, that is shewn by his estimate for doing it; for to make the bottom suitable to the bottom of the river at head and tail, it must be dug or washed away to the main depth of twenty feet below the surface of the present soil of the lands through which it is to pass, the broken ground excepted; but suppose there should happen to intervene some hard matter in the bottom, the current may then not act thereon, so as to grind it down to a proper depth, but, on the contrary, turn it aside, and make a fresh crook instead of the old one: such things may happen.

Now, I would be glad to appeal to any skilful and unprejudiced master of a ship, a person who has had the care of one of 300, 400, 500, or 600 tons, whether he would choose to lie in a gullet, where he cannot turn himself about, but if he goes in head forward, he will be obliged to go out sternforward, with large lighters or galberts by his side (or be obliged to lose this way), to tranship his cargo, and where other vessels of equal size will be obliged to rub by as well as they can, where he is subject to speats and floods coming down, which run like a sluice, as may be seen in the last made cut, into which floods in winter frequently bring down shoals of ice, and where, if the wind blows in or near the mouth of the gullet, the sea will have a fetch of three or four miles: I say, I would be glad to ask any experienced and unprejudiced ship-master, whether he would look upon this as any harbour at all, especially for large vessels? Certainly, he would answer in the negative: then pray, gentlemen, where is your harbour? Is it in the cuts now made above? no; these have the same objections, except that arising from the swell, with the addition of one still more in their disfavor, which is, that there is not water to get a ship of any burthen into them: the harbour must be then in the open reach of the river, between the tail of the last new made cut, and the head of the new proposed cut; but it must be below Jemmy Reay's ford; in short, it must be confined to a space in the natural river not above 200 yards in length, and where there is not above eleven or twelve feet of water at a neap tide, this very difficult of access in time of floods and speats, occasioned by a long narrow entry, and this is your excellent harbour of two miles in length! excellent, indeed, for the Carron smacks, as it will be the most likely means of banishing all larger vessels. Oh! but Mr. Golburne proposes to clear away the "stones and hard gravel near Reay's ford," by "dredging or ploughing, as shall be most convenient;" but I can tell Mr. Golburne, that he must dredge or plough, which ever he finds most convenient, and that pretty deep too in some places, a great part of the way between Reay's ford and Abbotshaugh, in order

to get two feet more of water than there now is. Mr. Golburne says, that the expense of cutting and completing the new channel will not exceed £3000*; but he does not say how much the dredging or ploughing Reay's ford, &c. will cost, nor whether the dam to be erected across the river Carron, in order to force the water through the new cut is included, nor how often that dam may chance to break down, before the Carron will submit to be controuled by it; nor how long the navigation may chance to be stopped after the dam is erected, while the channel is grinding down to a proper depth.

Mr. Golburne computes that there must be seven feet water in the channel of the Carron at neap tides, so that vessels drawing six feet run up the river at low water. Does Mr. Golburne mean that they now do so, or that they will do so when the cut is made, and Reay's ford dredged? does he mean at the Carron mouth or at Reay's ford, and quite up to the Carron wharfs? for I own myself perfectly at a loss to understand both the logic and the arithmetic of this paragraph. This however I am certain of, exclusive of theory, that instead of three feet water at low water, upon Reay's ford, I have been carried over the river upon a man's back, when he was not wet above half-way up the leg; and as there is not above eight feet water at high water over Reay's ford, I do know by the help of a little theory, that Reay's ford must be lowered about ten feet to make seven feet water at low water neap tides in dry seasons, which I believe is far lower than any part of the bottom of the river above Reay's ford, and will not cut itself out till a great way below it. Reay's ford is, I believe, (unless it is some accidental matter that may have been thrown out of the new cut which I reckon not upon), the shallowest part of the river, but I did not find, when I founded it in 1767, above six inches of clear navigable water more above than at Reay's ford.

I can readily agree with my brethren, that this new reformed Carron will afford an excellent harbour of two miles for a particular sort of vessels, and had I with them viewed those vessels through the same optic glasses, I might have thought all others of little consequence, when seen through the opposite end; so far so good; but what it was that could provoke my brother Brindley to call the present intended canal, a canal without a harbour! surprizes me. Had Mr. Gascoigne put the same little tract into Mr. Brindley's hands that he did into mine, I hope he would have had a better opinion of the harbour of Green brae, but perhaps the wind may be changed, and now blow
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* Mr. Golburne allows £100 a year for maintaining the new cut, which in effect is equivalent to a capital of £2000, so that the capital laid out upon completing this new cut will be £5000, a sum very far exceeding the extra cost of conveying the canal upon the surface.

right down the Hewk reach, and very hard, so that no vessels can enter: however, if he has no opinion of that, I must beg leave to inform him that I look upon the harbours of Leith and Borrowstonness, Port Glasgow, and Greenock, as well as many other harbours upon the Firths of Forth and Clyde, to be harbours to the canal, where they can tranship their goods on board of vessels; that whenever they can sail up the Forth and enter Carron mouth, they can enter the canal by one of the Hewk entries, or, if they like it still better, by the Carron entry, without troubling any wharf or warehouse, and by this means many trading places will partake of the benefit of this public spirited canal.

Mr. Brindley and Mr. Yeoman both agree in saying that the alteration of the river will not produce a bar: I cannot say it will, but this I say, that I do not know any thing more difficult to pronounce upon than the effects that attend alterations of natural rivers; and I appeal to them, whether they do not, as I do, find, that even alterations of the simplest kind are often attended with effects that were not foreseen; this I know from experience, that whatever increases the rapidity of a river, tends to form it into hills and holes; that the great quantity of matter that will be driven out of the new cut will be lodged some where, that the rapid water issuing from the tail of a contracted cut, will have a tendency to deepen Holmerrie, and deposit the matter at some distance beyond it, as happened on opening the last new cut, and therefore will naturally lodge it where the bar now is, consequently will have a tendency to encrease it; this is nothing but plain reasoning from plain matters of observation; let my brethren say otherwise.

I cannot quit this subject without taking notice of an assertion of Mr. Yeoman, on the 14th article; he says, "there is but one wind that can carry a vessel round the Hewk point, or even abreast thereof, after allowing every possible advantage of tide and fair weather." The harbour of Green brae is indeed very difficult of access, if there is but one wind by which it can be entered, and even not that "in a gale of wind:" very hard indeed brother Yeoman; I marvel much how the Carron Ship Company carry on their very extensive business under these difficulties.

As to the sea reach or Carron mouth, this is common to each project, and it is agreed that vessels can turn to windward therein; I have already stated that to vessels going upward, the Hewk reach will bear N. N. W. neither brother Yeoman nor I, are obliged by profession to be complete seamen; but I would be glad to ask any one that is so, whether he cannot sail up such a reach with the wind at W. and also with the wind at N. E.; and with all winds from N. E. round to W. taking in all the eastern

eastern and southern points, in short, taking in twenty parts in thirty-two of the whole compass; and as this reach has the Hewk farm on the larboard side, and a high steep bank of mud on the starboard, which is hardly covered at high water neap tides, whether even he cannot sail in with those winds, even in a gale of wind? also whether when at the head of this reach, a ship sailing in with a fair wind and tide of flood, may not shoot up sixty or seventy yards, so as to come abreast of the Hewk point with the wind right a-head in the turn of the point, where she will be at least in perfect security, and from whence she may if she pleases, warp herself to her proper birth, if she wants to stop there? nay further, whether small vessels drawing seven or eight feet water may not, where there is a breadth of four or five hundred feet, and a depth of at least $8\frac{1}{2}$ or nine feet at a neap tide high water, turn to windward, and weather this point; or work up the Green brae reach, if the wind being favourable in the former, and the turn of the Hewk should be right down that; and this even though a tier of ships and lighters should occupy the channel on one side? Those that deny the practicability of doing this in water perfectly land-locked, on all sides a clear shore, and nothing but soft mud to run upon; let them attend to the narrow passage often left between the tiers of vessels in the port of London, through which vessels of large sizes are obliged to work when the wind is foul, or to the narrow passage into the port of Shields, from the Black Middins to the Hird Sand; nay, further, whether a vessel before or after it has gained the Hewk point may not as easily be towed by horses through a large open river to the Grange burn foot, as it can through a narrow cut from Holmerrie to the same point; especially with a flood in the river?—As to any improvement above that place I oppose it not.

9th and 10th. I do not materially differ from my brethren, in answer to these questions; I have only to observe, that the land cannot be gained at a small charge, nor in my opinion in a small space of time.

11th. If cutting through the very tract proposed for the canal, or intersecting of it twice with the new cut, will be no obstruction to it, I do not know what will; I am therefore perfectly at a loss to know what my brethren mean, by asserting that it will be no obstruction.

12th. No more than will be according to the present design, as every one will lie as commodious for the Carron entry if they do not choose the other.

15th. The greatest part of what can be said on this head, has been already said; I

must however here take notice, that though both Mr. Brindley and Mr. Yeoman join in asserting that there will be no more obstruction from floods than at present, yet I would ask them whether the same quantity of water, passing through a small channel, must not move with a proportionably greater velocity, than in passing through a large one, and desire them or any one else to look at the last new cut in time of floods, and then tell me whether there is not more shelter for vessels from floods and from ice in the Eddys, occasioned by the turns of the river in its present state, (and a greater length too) than can be in a confined cut, in a right line, or so nearly so, where they can escape no part of it; I do not contend however that the river should be crooked, otherwise than to preserve the natural advantage of the harbour of Green brae.

16th. Some attention and some expense may be necessary, and I dare say any of my brethren can tell me how to do it whenever it becomes necessary, but upon what foundation Mr. Brindley says, that in case the river should break through this point, "the lock intended to be built at Grange burn would then be left inaccessible to vessels drawing six feet water," I cannot conceive; had he founded the Grange burn for a quarter of a mile upward, he would have found so much water, as, with his management, would have been able to have procured a passage of twice six feet of water.

17th. The connecting any side cuts, or cuts of communication, with the main undertaking, which I always understood to be a direct communication between sea and sea, was never according to my sentiments or advice. The Glasgow branch was a matter of necessity, arising from prior stipulation between parties, the end of which I never hesitated to say would, in my opinion, be more properly answered by the magistrates of Glasgow putting their act in execution for improving of the river; but who can compel them? With respect to the Carron entry it was no part of my plan; nor the connecting of it, as to proprietorship, with the main canal, any part of my advice; if therefore the gentlemen have, without being fully advised of the nature of the ground, inadvertently agreed to a thing that will lay any degree of embarrassment upon the main design, it is no fault of mine. In regard to the agreement referred to, I never had any copy of it, except one delivered me some months ago by Mr. Garbett, and which I profess myself not to understand. I have, at a public meeting of the proprietors, desired an authentic copy, with the precise terms of its meaning, but have not yet received it; and till then, I do not think myself justified in making any alterations in the track of the canal, or in taking notice of any paper that shall be delivered me by any person, whether proprietor, or not, unless it comes to me authenticated, as by
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the act is directed, and therefore till I do receive an authentic copy, and be made to understand what is meant to be executed by those alone whom I acknowledge to have the power to direct me, I cannot advise what is most proper to be done in the case as it is now circumstanced: but thus far I can advise, that if the proprietors do not think proper to confine themselves to a sole entry at Carron, I do not think the track pointed out by Mr. Brindley to be the adviseable one.

18th. Respecting this article Mr. Brindley says, in his preface, that his time would not permit to make "minute examination of the strata of the earth," yet, under this head, he says, "as I find the materials at the summit (or point of partition) very favourable, I recommend deep cutting at that place, not only for the saving of lockage, but with a view of acquiring very considerable quantities of new water." Mr. Yeoman recommends to cut as deep as we can, not so much with a view to save lockage, as to acquire more water. Mr. Mackell reports, from his examination in the summer, 1767, that the crust of peat earth is generally not above five feet thick, and under that, in every place he tried, there was quick mud; and as Mr. Brindley acknowledged verbally, that in such a soil deep cutting was not to be recommended, or any material quantity of water to be expected, there is an end to this business of deep cutting; I wish it may prove more favourable; but unless we can cut so deep as to save a lock's height, the rest will be no saving at all; and as to water I should be surprised if we did not raise some, to which I hope we may be justly entitled in consequence of what is remarked in pages 75 and 76 of the 2d report, but I think much water is not to be expected; because, if any communication with the hills produced any considerable pen, it would soon find its way through so thin a crust, and shew itself, especially as this crust has frequently been perforated, in digging peats. It is probable a quantity may be lodged under the crust, which may lie there inclosed, like water contained in a bladder, but which, when let off, there is an end of.

19th. Upon this query the two gentlemen seem divided; Mr. Brindley recommends to begin at the point of partition, because, he says, it is his "constant practice to do so, and, in the present undertaking, it seems particularly adviseable on many accounts:" but pray, Mr. Brindley, is there no way to do a thing right but the way you do? I wish you had been a little more explicit on the many accounts; I think you only mention one, and that is to give more time to examine the two ends; but pray, Mr. Brindley, if you were in a hurry, and the weather happened to be bad, so that you could not satisfy yourself concerning them, are the works to be immediately stopped when you blow the whistle, till you can come again, and make a more
mature

mature examination? and further, do you usually begin at the most difficult part of a work first, with raw hands, before they are trained to business? I have sometimes done so, and repented it. I think it no difficulty to make a hole in a hard or soft rock, because it is every day's practice; but I do apprehend some difficulty in getting even the necessary depth into Dolater bog, notwithstanding you find the materials there so very favourable. Mr. Yeoman very judiciously and very candidly observes, (and in that spirit all his remarks and answers are drawn up), that as he apprehends "in a country like this, where the canal is to pass through, it will be utterly impossible, at least it will be very inconvenient, to begin any where, and carry on the works in a progressive manner, without some intervals, because of the want of accommodations for workmen, and especially at the first setting out." I have often told the proprietors that nothing of consequence could be done this year, but merely to make a beginning, and get the workmen into training, so that they may afterwards be branched off to different parts; that for the sake of getting accommodations for workmen, without laying a difficulty upon them and the country in supplying and lodging them, it would be right to put on workmen at both ends, the middle, and also to the neck of the hill in the Allander passage, by which means the work may be carried on in five different places: besides, men may be set to different stations to cut the trenches, aqueducts, &c. but all this cannot be done at once, nor is there any necessity of pushing, 'till the plans can be made out, several of which are already done, and in Mr. Mackell's hands, before I went last into Scotland; and one very material and much wanted, viz. for the locks, 'would have been done, had I not been employed in answering these reports. As to what Mr. Brindley throws out about making dry cuts, I will be bound to say that he will not finish the canal in four years, as he asserted, nor as I think in twice four, if he carries his work progressively each way from the summit, in order to take the water with him; and as to such opportunities of filling the cuts with water from the summit, or as offer themselves from the rains in the winter, we should have done that, though he had not told us. Something of this kind is to be found at page 76, of my second report.

As to traffic from the summit, I have heard of none except Mr. Caddell's iron stone, which, as it only pays a penny per ton, I must be so just to the interest of the proprietors who employ me, as not to tell them that I think this an object which should induce them to put their works out of the regular course of proceeding. I am obliged to Mr. Yeoman in giving his sentiments of what he has seen done, and that whether in favour or disfavour.

20th and 21st. I have reported, and the engineers have confirmed it, in their replies to the first and second queries, that there is water enough for the navigation, and to supply what shall be taken from the mills; the act says expressly, that all such water as shall be taken from the sources of the rivers Carron and Kelvin, to the detriment of the mills specified, shall be replaced in kind: this being the case, I do not see why the proprietors should be prescribed to, as to their mode of doing it. If they are the showers the Carron company so much covet, we can give them sufficient of that from the head of the Enrick, to compensate the drainage of Dolater bog, and the hill sides along which the canal is carried; but as we propose to make tunnels and aqueducts to give the burns and runners their natural course, and to take nothing into the canal that we can help, beyond our proper supplies; and since all superfluous water taken in must be discharged at the over-falls, as it cannot be used, I would ask my brethren, whether, after this, a much more material drainage is not likely to arise from the soakage of the canal, and the Dolater reservoir, notwithstanding all the care and pains that either they or I can take; and since I have demonstrated, see report second, page 80, that the Dolater reservoir alone will be capable of holding water that will supply the canal one quarter of a year, and all deficiencies for three quarters of a year; I hope we may take the opportunity of filling it in winter, or great downfalls of rain, when twenty times as much water as they can use at Carron is running waste over the dam-heads, after all their reservoirs are full: it is our business only to give them as good means of filling their reservoirs, as they now have, not to enlarge their reservoir at Larbert, nor procure them Loch Coulter from Stirling mills; in short, I can see no other use of these two queries, but to raise difficulties where there are none.

I come now to take notice of such supplemental articles as my brethren have thought proper to add, which have not fallen in with some part of the foregoing observations. The principal is, they have found out a new road, more near and convenient for the city of Glasgow; but I must beg the gentlemen to reflect, that whatever they have been upon, my object was a communication between sea and sea, and a branch to Glasgow as per treaty. I have as high an idea of the trade and importance of Glasgow as they can have, and wish as well thereto; and for this reason, should have been most heartily glad that Glasgow had stood at Dalmoore burn foot: yet, notwithstanding all they have said, I can by no means give up the entry there; but as Glasgow stands not there, I further wish, that at any moderate expense, the canal could have been extended below Dumbuck.

The

The passage they hint at, and which is in some measure described by Mr. Yeoman, is due to the assiduity and sagacity of Mr. Mackell, who found it out after he left London, in the spring, 1767, and during the time he was employed in reconnoitring, previous to my review in August, 1768, and who then shewed it to me; and it was shewn to Mr. Brindley by Mr. Laurie, the surveyor, and which passage, on consideration, I rejected for the following reasons.

1st. The ground from Calder bridge to the passage over Kelvin, at the Printfield, is in general rough, and some part of it very rough and crooked.

2dly. A rise of more than twenty feet for near a quarter of a mile above the level of the canal on one side, and almost as high on the other, but for a shorter length.

3dly. A very deep and wide valley to cross the Kelvin, by a very large aqueduct bridge.

These appearances made me judge that the expense of this passage would considerably exceed the expense of cutting the Allander summit, especially as I had then in view the carrying the canal upon a higher level, and saving a considerable quantity of cutting in that summit, and which I have now still more reason to think is practicable. Add to this, as we had no other view than to go to Dalmoore burn foot, it appeared to me not only considerably more winding, but further about from sea to sea, though Mr. Mackell thought otherwise respecting the distance.

The communication to Glasgow would, indeed, be somewhat shorter, but then it parted from the main canal at such an elevation, as to require several locks to go down to Glasgow, which would not only be expensive, but require water to work them; whereas, in the way the Glasgow branch was planned, it not only required no extra lock or water, but laid so nearly parallel to the river, that it might be used for a communication from Glasgow to Port Glasgow and Greenock, and back again; which, though no part of the stipulation, as I considered the branch canal as a dead weight upon the main undertaking, this circumstance might make it answer better, and be a proportionable advantage to the trade of Glasgow, there being no appearance then of the Clyde's being improved. It was in vain to say—gentlemen, you may make a branch canal of your own river, by putting your act in execution.—No, we must have a branch canal of equal dimensions; but if Messrs. Brindley, Yeoman, and Golburne, have
again

again caused the magistrates of Glasgow to resume the improvement of the river, as I am convinced in my own opinion, that the track marked out in the act of parliament for the main canal; is upon the whole the preferable track; the truly wise, and sensible thing will be to give the Glasgow gentlemen a branch cut, from near the three part mill dam into the Clyde, below Blart hill, as hinted at before; and though this will cost them at least three locks, with water to work them, yet the proprietors had better be at the expense of these locks, and procuring this water, than carry the canal over the Kelvin through the valuable grounds near Glasgow. Where Mr. Brindley's canal was to terminate does not appear; this he has reserved for the next time he comes; but Mr. Yeoman's termination at the Holme Sands I can by no means approve, not only because that is the most precarious part of the whole river, and because it lies in the power of other persons to remove the impediment or not, but also because there is another circumstance, that Mr. Yeoman possibly was not acquainted with, which is, that if the magistrates of Glasgow only order the stones to be thrown into the river, that John Adam laid down at Marlin ford in the year 1760, for building a dam there, they may levy one shilling per ton upon all vessels passing that place, and thereby lay the canal under a heavy contribution.

That my brother Brindley should prefer the Printfield passage I can readily comprehend: a late author has very solidly demonstrated, that every man, how great soever his genius, has a certain hobby horse that he likes to ride; a large aqueduct bridge over a large river does not happen to be mine, who am of opinion, that a given sum of money is as solidly laid out for posterity in cutting through the neck of a hill, as in building a bridge to carry water over water, though the admirers of the wonderful may not be so loud in their applauses.

As to Mr. Brindley's 4th and 7th supplemental observations, which have not been touched upon before, I could have told him the same things if I had met with him in Staffordshire.

I ask Mr. Golburne's pardon for not attending before to one of his observations: he finds Holmerrie not above 100 yards long, and not above five feet deeper than the bar, whereas I have stated it at seven feet deeper than the bar, and a much greater length. I did not measure the length; but I sounded the depth, and found the deepest part seven feet deeper than the bar: this was during the very first spout that happened after the last new cut was opened, out of which first and last there has been driven a great quantity of matter: I therefore would ask Mr. Golburne's opinion, whether some
of

of the matter out of the new cut may not since that time have been lodged in Holmerrie, or that my pilots were as solicitous to find out the greatest depth, as his were to find the least? be this as it may, the channel of the river in this place is for a great width deeper than the bar, and the bottom soft mud, so that vessels cannot be hurt in lying thereon, in three or four feet water at low water, though Holmerrie should be quite filled up; or if two or three at a time, weaker than the rest, cannot bear it, they may still find a birth in Holmerrie, in case Mr. Golburne will not quite fill it up with the matter out of the new proposed cut.

Having now gone through every article that seems of consequence to the right understanding of the business in hand, I have only further to add, that for my own part I see nothing to oppose this great work's being brought to a timely issue, but the different opinions of men, and I should not despair of seeing it executed, even with the remnant of time that I have in my power to apply to it, in case I am suffered to go on with the work according to my own experience and ideas; but if engineers are to be constantly brought down to inspect and see how the pot boils, I think neither I nor any other man can go on with it, to the advantage of the proprietors, under such circumstances, any more than I could sit down at the cross of Edinburgh, and write this answer to my brethren, while every one at pleasure had an opportunity of overlooking and asking me why I begun this paragraph in this manner, or treated that subject thus.—If, instead of making plans, I am to be employed in answering papers and queries, it will be impossible for me to go on with the business, and therefore perhaps those that wish no good to the undertaking may be desirous of furnishing me with this kind of materials. All the favour I desire of the proprietors is, that if I am thought capable of the undertaking, I may go on with it coolly and quietly, and whenever that to them shall appear doubtful, that I may have my dismissal.

28th October, 1768.

J. SMEATON.

COMPARATIVE VIEW of the expenses upon the works of the Forth and Clyde canal, as per general account, down to Christmas, 1771, with the original estimate:

	£	s.	d.
By account of materials, freight and carriage thereof, workmanship, digging, and temporary damages	-	-	71,747 12 2
Estimate of the whole, per second report	£147,337	0 0	
Carried forward	-	-	71,747 12 2

Estimate

	£	s.	d.	£	s.	d.
Brought over	147,337	0	0	71,747	12	2
Estimate of additional expense of the new line, neat valuation	1,734	0	0			
Ten per cent. thereon for contingencies	173	8	0			
Total sum estimated	149,244	8	0			
Total land purchase	£13,544	0	0			
Ten per cent. on ditto	1,354	8	0			
Deduct	14,898	8	0			
Total of materials and workmanship, valued per estimate	134,346	0	0			
Ditto of the Glasgow branch, deduct	13,007	7	4			
Remains for the main canal as now	121,338	12	8			
Remains of the estimate to be expended	49,591	0	6			
Difference of past expense and of that to come	21,155	11	8			

N. B. If it is supposed that the works were half done at Christmas last, then the expense will exceed the estimate by about $\frac{1}{6}$. But if the expense of the Glasgow branch be given to this work, then the exceeding will be but about $\frac{1}{16}$ th.

(Sic. subtr.)

J. SMEATON.

Edinburgh, 3d August, 1772.

A PLAN or model for carrying on the mechanical part of the works of the canal from Forth to Clyde, by J. SMEATON.

Engineer in chief.

Engineer resident.

Surveyor of the eastern department.

Surveyor of the middle department.

Surveyor of the western department.

To each of the surveyors, a foreman of the

{ Digging,
Carpentry,
Masonry.

Their duty as follows :

Engineer in chief.

- 1st. To make plans for execution of such works as shall be directed by the committee.
- 2dly. To pitch upon the ground whereon the said works are to be constructed.
- 3dly. To correspond with the committee upon such points as they shall think necessary.
- 4thly. To correspond with the engineer resident, and send such directions from time to time as himself or the resident shall find necessary.

Engineer resident.

- 1st. To attend such meetings of the committee as he shall be ordered to attend, or such meetings as he shall think necessary to procure directions.
- 2dly. To see the plans and directions of the engineer in chief put into execution.
- 3dly. To mark out the grounds to be purchased, and to enter into such treaty with the proprietors as he shall be directed by the committee.

4thly. To

4thly. To supply such plans and directions for the lesser part of the work as he shall be desired by the engineer in chief, or which his absence, or the necessity of the case shall make expedient.

5thly. To correspond regularly with the engineer in chief.

6thly. To give a monthly account of the state of the works to the committee, or oftener, if required, and to send a duplicate to the engineer in chief.

7thly. To attend each part of the work upon any emergency or difficulty, and also to see all new matters or methods put rightly in hand.

8thly. To survey the materials, and make such purchases thereof as directed by the committee.

9thly. To visit all the works from end to end as often as possible.

N. B. It is supposed that the resident engineer ought to have power of employing a land surveyor, if occasion, to measure and survey the lands, and to have power of discharging any officer under him on neglect of duty.

Surveyors of particular districts.

1st. To attend to the orders of the engineer resident.

2dly. To see the proper quantities, qualities, and conversion of the materials committed to his care.

3dly. To order the foremen concerning the works whereon they are to employ themselves.

4thly. To transmit an account weekly of the progress of the works to the engineer resident, and of what materials, &c. are wanted.

5thly. To receive the necessary wages from the pay-clerk, and account with him for the money.

6thly. To

6thly. To reside as near as may be to the place where the principal works are under his care, to visit them daily, and the most distant once a week, or as often as possible.

Foreman of particular branches.

1st. To observe the directions of his surveyor.

2dly. To see all his men as often as possible, and to see that they keep to their labour.

3dly. To receive money from the surveyor, and pay the men, of whom he is the overseer, keeping a daily account for each particular man, and delivering a duplicate to the surveyor, in order to be transmitted to the committee.

N. B. As gangs or fetts of men must necessarily be employed at different places under the same foreman, some one of these must be appointed overman of a gang: it is presumed that the overman may act as clerk of the check to his gang, and give an account of their time to his foreman.

To prevent abuses, the engineer resident to have inspection of all papers and accounts of the officers under him, whenever he thinks it necessary, or is ordered so to do by the committee.

(Signed)

J. SMEATON.

London, 14th March, 1768.

CALDER

CALDER NAVIGATION.

The REPORT of JOHN SMEATON, engineer, concerning the state of the Calder navigation, from a view thereof, taken the 25th and 26th days of November, 1767.

See a map of the Calder, vol. i. p. 21.

GREAT damages having happened, particularly to the banks and spade work of the Calder navigation, from a flood in the night between the 7th and 8th of October last; on a view thereof, I made the following observations: That the river was in this flood, by marks at Horbury mill, two feet ten inches perpendicular higher than any flood which has happened since the river was first surveyed by me in the year 1757; that at Minfield Low mill it was above four feet higher, and at Brighouse three feet eleven inches; that, in fact, it was higher than any flood in man's memory, or of which there is any tradition, being universally allowed to be higher than an extraordinary flood which happened about forty years ago; which, in the neighbourhood of the Calder, is distinguished by the name of Bowman's flood, and which was always reported to me to be the highest ever known: but the flood of October last, by the marks at Horbury mill, (and the testimony of John Horn, a millwright, who has worked there and at Wakefield mills ever since Bowman's flood, and remembers it), appears to have been four inches higher at Horbury mill, than Bowman's flood, and as in the late flood the rise was more considerable in the highest part of the river than below; these facts being considered, it seems more marvelous that the works have not been wholly swept away, rather than that they have been broken in particular places.

In order to guard the navigation as much as possible from such an extraordinary event as Bowman's flood was reported to be; it was always my intention, and which I have verbally mentioned to the commissioners, while I was concerned, that as soon as the navigation was opened to Brook's mouth, to build flood-gates like those at Dewsbury upper mills, at the head of Thorn's, Batty's, and Kirklee's cuts, and also to make up and defend the banks in particular places to an extra height and strength; and, had this been put into execution, I cannot help saying, that the damages on the present occasion had laid in much less compass, though probably not entirely prevented.

It

It appears from this view that the banks for by very far the greatest part have withstood the flood, and that in those places where they have failed, it has not been by their bursting, but by the waters overflowing their tops, and have been either cut down in consequence of a current overflowing them, or beaten down by the waves raised by the wind, which, in the decline of these floods, was very violent, and which last cause of disaster might be prevented by covering them over with rubble stones, where so particularly exposed: it appears also, that nothing of consequence has happened to any of the capital works, viz. the locks and dams; for though two or three of the locks have suffered some damage, yet this has not been occasioned by any failure in point of construction, but by an attack from without, arising solely from the failure of the banks: the worst of these being Batty's lock, one of whose chamber walls was washed down piecemeal into the lock, by a current of water setting across the top of the wall, from a breach in the bank at the lock-head; yet even in this situation of distress, the pillars to which the gates were hung were left standing.

From hence it appears practicable, by guarding against the disasters that now have happened, partly by increasing the height and strength of the banks in particular places, and partly by the erection of flood-gates, not only in the three cuts above mentioned, but in some others that now appear to be much exposed, that this navigation might be made as safe against such floods as the great flood of October last, as it appears to have been before against all such as happen in the common course of nature.

The great difficulty and risk attending the navigation is during the course of the present winter, till the season comes in which the necessary works of safety may be performed; for till the breaches are made up, the navigation is liable to be interrupted, and what is already done in the way of repair, destroyed by common floods overtopping those places not fully made up, and this can only be prevented by a timely and speedy application of a sum of money to effect those purposes; and which, if speedily applied, and the season continues favorable, I hope will not be considerable in proportion to what has been already laid out: but as it depends upon circumstances of weather not to be foreseen; and when things are obliged to be done at a push, are necessarily done at a great disadvantage in point of expense, there is no possibility of making any regular estimate. But, supposing the navigation to be saved by a seasonable application till the winter is over, I am of opinion that the sum of £3,000 directly laid out during the course of next summer in erecting the necessary works and defences, will give a reasonable expectation of seeing such another flood pass over without interruption to the navigation, at least, by the failure of any of its own works; for it is to be observed, that by the failure of

Dewsbury

Dewsbury dam, belonging to Mr. Greenwood, the navigation would have been interrupted the greatest part, if not the whole time, that it may probably now be, had nothing particularly happened to the Calder works.

It appears to me, that eight, or at most nine pair of gates, with proper bankings in particular places, as before mentioned, will be sufficient, and all the materials being prepared and laid down upon the respective places, and the works divided into two, or perhaps three classes, that the works of each class may be got above water, without interrupting the navigation above ten days at each time, which, as it will be at intervals known beforehand, will, I apprehend, be no material detriment.

Gates upon Thorn's Ledger, Batty, and Kirklee's cuts, appear the most necessary; but I shall not prolong this discourse at present, by entering into the detail of what ought to be done in future; for in case this proposition is resolved upon by the commissioners, which seems to me the most likely, and perhaps the only way of giving a lasting security to the good effects of this navigation to the public, and to the property of those who have ventured thereupon: though I both am, and expect to be, much hurried in business, yet I shall not be wanting in giving my best advice concerning the proper placing and construction of the proposed works, if thereto desired.

J. SMEATON.

Austhorpe, 30th November, 1767.

CALDER

Mr. SMEATON, having viewed the river Calder, the 26th and 27th of December, 1770, reports as follows:

HE has the pleasure to inform the company of proprietors, that he finds the river now put into as good a state of security as could possibly be expected in the time, and is, indeed, in general, in a very defensible condition; but to give the works every possible degree of security against the extremes of floods, he begs leave to subjoin the following remarks.

WAKEFIELD.

The heels of the flood-gates to be breasted up about one foot, and the banks made good to the bridge.

THORN'S CUT.

The flood-gates to be breasted and continued one foot higher to the high bank.

LUPSIT DAM.

The old setting in the body of the dam to be taken up and used as footing stones to a rubble body; the footing stones to be disposed in the arch of a circle, like the original dam, and from thence lagged up with an even slope to a proper height; the materials there rather want putting in order, than any great addition.

HORBURY BRIDGE.

The bottom, under the navigation bridge, to be filled with rubble, to such a height as to allow navigation water only; this will strengthen the bottom when the water goes over the bank below next the land, and prevent so much from flowing through the bridge. The bank next the river from the bridge to the lock to be heightened by a new cover, and also a little above bridge to be raised, and to be rubbled next the river where worn.

LONG CUT.

The banks to be raised and strengthened a little above and below Mr. Walker's bridge.

The

The bank on the west side of the cut, for forty or fifty yards above where the old bridge stood, at Noel pond, to be a little raised with lagged rubble, so as to prevent the water going over that part before it does over the lagging at Noel pond.

BATTY MILL CUT.

About sixty yards of the bank, next the land below the bridge, to be lowered so as to be eighteen inches lower than the rest of the banking below bridge, and to be lagged over, that the back water which, unavoidably, will get into the cut above, may be discharged there without breach of banks; the place in the bank next the river, just below the flood-gates, to be well secured by an addition of rubble, where it has been attacked by the late floods.

KIRKLEE'S CUT.

The bank on the south side the cut, above the flood-gates, to be rubbled over on the back side with small rubble, to prevent the wind wash of the water from taking it down when the banks belonging to the farm break above.

ANCHOR PITT.

Some rubble wanting to secure the tail of the dam's end wall, on the Bradley side.

LILLANDS.

The bank above the lock on the side next Lillands, to be made good with rubble behind the hedge.

GOOL CUT.

The bank next the river below the flood-gates to be made good to prevent the rivers breaking into the cut.

SOWERBY BRIDGE CUT.

When the water is off, to examine the places whereabouts the runs are, and to carefully tread and beat the earth that should line the same; if this is not effectual, a further deposition of ashes will be of use, and probably in time stop of themselves.

The method now taken of increasing the weight and strength of the banks, which slide on the side next the river, and diminishing those on the opposite side, is the most likely way to make them effectual.

It seems to me that water will be best brought into the cut from the river Calder, by carrying a fough through the high ground behind the housing of the town of Sowerby bridge; its dimensions and depth will depend upon the level, whether it can come from Sowerby bridge dam, or thither by an open cast from Holling's mill dam, and if the latter must be brought by a fough through the high ground contiguous to that mill, which level being taken, Mr. Smeaton will further advise.

J. SMEATON.

Austhorpe, Jan. 16th, 1771.

To Mr. Thomas Simpson, clerk to the company
of proprietors of the Calder and Keble na-
vigation.

The REPORT of JOHN SMEATON, engineer, upon the means of improving the navigation of the rivers Aire and Calder, from the free and open tideway to the towns of Leeds and Wakefield respectively.

FROM a careful inspection of these rivers, it appears to me, that the original projectors of the navigation, not having had any notion of the extensive trade that was likely to be carried on by means thereof, have formed their plan upon too diminutive a scale, and particularly with respect to depth or draft of water. This appears plain from this circumstance, that several of the thresholds of the locks have been laid so high in some of the most critical places, that with full ponds in the ordinary state of the river, there is not above two feet six inches of water over the thresholds; and also not being aware that it would become the practice of millers to draw and keep down their ponds, in order to levy contributions on the navigation; though as to what concerns the working of the mills, it is manifestly their interest to endeavour to keep them full; the navigation has always laboured under difficulties on these accounts.

The level of the lock thresholds evinces what the views of the first projectors were respecting the construction of the navigation, and had this been the only fault, it would have been possible, by the re-building these locks, to have amended it; but the same idea, by endeavouring to save locks in point of number, and to save length of cutting, has tempted them to carry the locks too far upwards, so as to leave shoal spaces in the river for a considerable distance below.

Nor do these impediments last described occur only within the compass of the locks, or the artificial part of the navigation, for they equally subsist below the lowest lock, which is at Haddesey; and though the spring tides there in ordinary make six feet additional water, yet the neaps do not commonly reach thither, so that in those cases in ordinary dry seasons, there will not be two feet of water up to Haddesey lock at high-water neap tides: this is the case, not only within the limits of the present navigation, as subject to act of parliament, that is, down to Weeland, but there is also a considerable shoal equally as bad as any of the rest, that lies about a mile below Weeland, called Stock Reach, over which, though the neap tides sensibly flow, yet they do not make, in the whole, above two feet depth of water, and it is plain that no very material change for the worse has happened in the river since the navigation was begun, because the
depth

depth of water upon the lower gate threshold of Haddelsey lock corresponds with the present depth over the shoals aforementioned, nor would there be the water below the said lock, within the limits of the act of parliament, that there really is, were not the bottom of the river worn down at a place called the Hurst, by weirs, which at best do their business imperfectly, and are subject to be torn away by every land flood.

To carry on a navigation under these disadvantages in dry seasons, they have early had recourse to flashes, that is, by drawing down the water out of such of the dams as were built by the navigation, and by doing this as it were altogether upon the two rivers there is created in the spaces below an artificial fresh, which enables vessels drawing $3\frac{1}{2}$ feet water to move for a time; but as the creating this fresh below drains the ponds above, they require in dry seasons such a length of time to fill, that it frequently happens they cannot give above two flashes per week, and those flashes last but for a short space of time, so that vessels going down therewith, being crowded together, are unavoidably stopped in passing every lock; so that while that is doing, the flashes are spending, those that are foremost stand the best chance, while those behind are frequently caught by the keel: so that taking the chances they seldom get upon an average above two ponds per flash, going down, and in coming up, or meeting the flash, they seldom get, at an average, above one; wherefore, vessels will be frequently from Stock Reach to Leeds or Wakefield, a week or more in making good their passage, that otherwise would be performed in fifteen hours. Hence, there is a necessity of a greater number of vessels being employed upon the river than would otherwise be sufficient to do the business, and, in consequence, a great deal of time necessarily rendered vacant to the boatmen, &c.; hence arises a manifest detriment to the public from so great a number of vessels and men lying unemployed, whose hire and wages upon the whole must be made good by the consumers, and hence complaints of the boatmen, who rather than be perfectly idle, often employ themselves in doing mischief.

It is manifest, that these stoppages, which last in a greater or less degree for several months in the year, must in their own nature produce the necessity of employing a much greater number of boats and men than would otherwise do the business; yet, if a number were employed sufficient to do the business in the flash seasons, there would not be half employ for them the rest of the year; it follows, therefore, that in those seasons, the business done, notwithstanding every effort, will be far short of the demands of the public: hence great complaints, for want of dispatch, against the rivers, and against the undertakers, and from those who, if they were apprized of the difficulties and disadvantages under which the business must be done, would be surprized how so much is performed in such a way.

The

The mills also complain of the water in dry seasons being brought down in flashes, that a great part of it runs waste over their dams, and that they are thereby deprived of a regular supply, and are obliged to wait a considerable time to get their ponds filled again, which complaint, though just, I apprehend has originally been brought upon themselves by their drawing down their ponds, which in return suggested the practice to the navigators drawing their ponds in order to fill the others: thus the mischief by one party's endeavour to draw down, and the other to fill, becomes accumulated, and which, with the present trade upon the river, it seems to me that nothing can remedy but a different mode of navigating.

To propose an adequate remedy for these obstructions and impediments with as little detriment as possible to private property, the proprietors of the navigation applied to me, and of this I shall now endeavour to acquit myself in the best manner I am able. In doing this I shall not take upon me to consider this matter in so extensive a light, as if the navigation had never been made; but keeping to the present tract and works wherever it can be properly done, I shall content myself with such alterations as appear necessary to procure the essential of a navigation, viz. the means of keeping vessels always afloat, so as to move freely in either direction when in the proper channel of navigation, and when not loaded beyond a proper draft of water.

Having carefully viewed and sounded both rivers from the towns of Leeds and Wakefield, to Carlton Ferry, near Snaith, I find on comparing those soundings that the rivers are capable (after making such alterations as in any view of improvement seem indispensable) of being made to carry vessels drawing three feet six inches water in dry seasons, and at other times four feet in its ordinary state, which according to the present sizes of vessels will carry thirty tons, and forty five tons respectively.

Experience teaches us, that one of the greatest impediments to navigation is that of navigating in mill dams, yet without forming this navigation wholly anew it is hardly possible to avoid it totally. I therefore lay it down that in order to secure three feet six inches water in mill dams in dry seasons, that there ought to be made five feet at a full head; this will allow the miller to draw off eighteen inches, which will give him a very sufficient scope, and yet reserve three feet six inches to the navigation: this will be consistent with the millers' interest, as mills expend more water as they draw down to do the same business, and few on this river will do any good execution when drawn down this quantity, the more they are drawn down, the more time they will take to fill, so that what is more than the scope abovementioned cannot in my opinion be considered

sidered in any other light than as means of hurting the navigation; and if it can possibly be supposed (which I cannot suppose) that any advantage can arise from drawing lower than eighteen inches within head, yet this will be compensated ten-fold, by saving all the water now expended in flashing, which I look upon to be far more than what is consumed in the necessary and proper lockage of the vessels. Drawing therefore the line here, as perfectly reasonable, in order to prevent disputes with the millers, that the navigators be at liberty to diminish the depth of the river in some proper place between the head of the navigation cut and the mill dam respectively, so as to form an artificial shoal, the top of which, in the lowest part, not to be less than two feet beneath the water's surface at a full head.

ALTERATIONS PROPOSED.

Beginning therefore at Leeds, I propose the following principal alterations. Just below the warehouse a shoal will require to be dredged, and another formed below the head of the cut: the cut above the lock to be dug deeper, so as to make five feet water at a full dam, as far as the elbow, and all the thresholds being considerably too high the lock must be rebuilt, and as the tail cut and river below are too shallow, and the deepening both is expensive and uncertain, I propose to extend the cut, and place the new lock lower down, which will drop the vessels into deep water; the river then holds good, or may be made so, with a little help, to Hunslett mill.

Hunslett mill lock, New mill lock, and Twaite mill lock lie all too high, and at all events conformably to what is above stated must be rebuilt; the cuts are all too shallow, both above and below, as well as intermediate shoals in the open river, and as the ponds are short, and thereby the mills can the more readily draw them down, this space is subject to every species of embarrassment, to avoid which I propose to take a cut out of the river a little above Hunslett mill, and forming a shoal (as before mentioned) to cross a corner of the Breaks, to cross a close of Sir William Milner's, another of Mr. Cookson's, Sir William Milner's again, and lastly through a pasture of the Right Honourable Lord Irwin's, commonly called Clark's pasture, skirting the high ground, and then falling into the river; this cut will scarcely be a mile in the whole, and will pass all the three mills at once. Flood-gates will be necessary at the head, to keep the floods out of the cut; two locks will be sufficient, with bridges and tunnels, to communicate the roads and water-courses, the hawling tract being upon one of the banks may be fenced off, if thought necessary.

There

There are three shoals between the elbow and the tail of the present cut ; as they are rocky scalps they may be taken up without interrupting the present navigation, or to avoid them, the cut may be extended about 150 yards, so as to fall into the river opposite the present lock.

Ryder shoal will need a little clearing, as also one below Mr. Fenton's staith : the dam boards will be necessary, as at present, in dry seasons, but may be made to strike at any time of flood, with far more ease than at present.

Cryer cut will want a little deepening towards the head, and the north bank making good.

Woodlesford lock, its bottom lies too high by about $2\frac{1}{2}$ feet, but the river being embarrassed with shoals below it, the laying it deeper would be to no purpose ; it will be necessary therefore either to build an intermediate dam and lock above Swillington bridge, or to continue Cryer's cut till it can be dropped into deep water above Swillington bridge, the latter, as it will leave the river free from additional dams, is in many respects to be preferred, but, as it would occasion the cut to cross the broad flat part of the valley, and to join the river where there is little flat ground on the opposite side, the water would in time of great floods become too much confined. What I think the most eligible is to continue Cryer's cut along the face of the high ground below the housing of Woodlesford, and crossing the road (from Wakefield to Swillington bridge) to carry it along the skirt of the high ground of Woodlesford field to the Oak Tree close, then to cross to the point of high ground belonging to Mr. Blades, and from thence to the tail of the cut of Fleet Mill lock, by which the shoals at Woodlesford, and the draft of Fleet Mill will be avoided together. This new cut will be nearly a mile, and to be furnished with proper bridges and tunnels.

Mithley lock bottom is also too high, and there being shoals all the way down, almost to Sir William Lowther's staith, that cut to be lengthened, and a new lock and flood-gates at the head.

From hence to Castleford, good water, with present dam boards there ; but, if any alteration should take place, the navigation should have power to build a new dam below the joining of the two rivers, in order to keep the water to its present height up them both.

The bottom of Castleford lock lies too high by two feet nine inches, and the river below is greatly embarrassed with shoals both above bridge and below, insomuch that in the present state of things, vessels could not pass Castleford without flashes, even if Knottingley dam were always kept full; those embarrassments will be all avoided together by a cut from the mouth of the two rivers across Castleford Ings to the elbow below Castleford, being a little more than a quarter of a mile in length, with a new lock, road bridge, and flood-gates at the head.

From hence the river continues very good till a little below the tail of Brotherton weirs, where there is a shoal having but four feet two inches water, and one below Ferry bridge, which has only three feet eleven inches, with a full pond at Knottingley, so that with the great number of mill cloughs and waste cloughs upon this head of water, it can, in all common seasons, be reduced so as to lay the loaded vessels a-ground upon the shoals last mentioned. But this is not all, for even though Knottingley mill were always to keep a full head, the river, for about a mile below Knottingley lock, is so greatly embarrassed with shoals, that with a full pond at Beal dam (the next below) there will not be above a foot of water in some parts of this space, and for the greatest part of that space not two feet, and at a medium about eighteen inches, and so great is the tendency of the river to silt and form obstructions in this part, that though weirs for the whole length have been maintained for a long course of years at a very considerable expense, yet this part of the river seems to be in a state of growing rather worse than better, and even if it were, at a great expense, to be dug deeper, so great a quantity of loose sand is lodged by the floods, that there is no answering that it would not choak up almost as fast as it can be deepened. The expedient for passing these shoals has been by putting boards upon Beal's dam, in two heights, so as to raise the water two feet above the dam's crown; and as those boards cannot be so easily disengaged in two heights as in one, they have frequently been obliged to remain during the course of flood, which has produced complaints from the land-owners in regard to the overflowing of their lands, and from the proprietor of Knottingley mill, in regard to its being sooner put into back water, the only certain and adequate remedy therefore that I see, is to form a new cut by all those obstructions from deep water to deep water, which will be done by departing from the river a little below Brotherton weirs, and from hence pursuing the general boundary of the north side of Brotherton marsh, and falling into the river into the bend below Anfleet drain, from whence the river is very good to Beal, especially with one height of boards, which may be made to strike as before mentioned, in any time of flood, or it will do without the boards, by taking a cut out of the river, just below the bridge-house, and joining it to the elbow of the
present

present cut above the lock; but I prefer the former expedient, as in this case the more easy, and because it will also retain more water at Knottingley weir.

The cut through Brotherton marsh to have flood-gates at the head, or joined to the great road-bridge for conveying the north road over the cut, a road-bridge answerable to Sutton-lane, and tunnels for the drainage water of the Anfleet. A shoal two feet under dam's height, below the head of the cut, will be wanted to retain navigable water from Castleford, and by way of communicating the navigation to Ferry-bridge, Knottingley mills, &c. a side cut will be required by the said shoal, with a pair of provisional stop-gates, to be shut only in case of the water above being reduced till it is penned by the shoal.

In order to prevent too much confinement to the water in high floods, I propose that for sixty yards, near the bottom of the marsh, the banks of the cut to be laid low and secured, so that the water may find a passage there as at present.

The lock of Beal is almost the only one upon the river Aire that lies deep enough, and from thence to Haddesley there is good water, with one height of boards at Haddesley dam, which may be made to strike as the rest do; at present two sets of dam boards (as on Beal dam) are frequently found useful for penning a greater pond of water to produce flashes below.

The open river below Haddesley lock, for nearly three quarters of a mile is, embarrassed with continual shoals, which again occur at the Hurst, and where, notwithstanding the weirs constructed for that purpose, the water is not better, for being the place whereabouts the neap tides generally terminate, the warp constantly fluctuating in the tides way, has a tendency to settle in this place, and consequently in dry seasons the bottom is the highest, when it is most wanted to be low. These obstructions are within the limits of the present act of parliament, but the shoal at stock reach about a mile below Weeland, being without the limits of the present act, admits of no palliation, but as it has nearly the same water upon it at high water as the shoals above, it has no other ill effect than increasing the number of places where the vessels are subject to be stopped: but, however, as by this means a tide is frequently lost, it certainly, even in the present state of the navigation, is a considerable object.

The most obvious way of curing these shoals is by building a lock and dam at, or below, the Stock Reach, so as to pen a sufficiency of water over them altogether, but

besides that dams should always be avoided where they reasonably can be, there is in this place this objection, that as the spring tides would flow several feet over the dam, and bring with them a great quantity of warp, it must be expected to subside in the still water made by this dam, so as probably to increase the present or produce new shallows, as bad as those intended to be cured; besides, as in the present state of the river, there are shallows still below, particularly at the top of Snaith's marsh, and Carleton ferry, where there is but just a sufficiency of water at neap tides, it is no ways certain, that the stopping of the neap tides more early than usual by the new dam above, may contribute to the raising those shoals still higher, and thereby to create new obstructions, which in the present settled state of the river, is not to be expected.

What I therefore propose is to take a cut or canal out of the river, just above the present lock of Haddesey, and crossing a small part of Haddesey marsh, to fall in with the hedge of Longcroft, and crossing Egbar Lees, the old Eye, and boggy ground below Sherwood, to make towards the high ground, opposite to Tranmore house, and there skirting the border of the high ground near the arable fields and marshes to go on to Henfall common, and keeping nearly the direction of the sea bank (on the marsh side of it) till we get to Gowdale marshes and the Intake, and pursuing that boundary nearly, to fall into the river a little above Gowdale lodge clough, where the river being deep, the vessels can be made to lock out and in at low water, and lie ready to save their tide over the shoal at Snaith's marsh and Carleton ferry, over which shoals, according to my observations and information, vessels loaded as before mentioned, are always secure of a passage at high water.

In the cut before mentioned, a large tunnel will be required for the passage of the water of the old Eye under the canal at Edgar Lees, and to give the usual passage to the water in high floods and breach of banks from above, I propose the banks of the canal near the old Eye to be made low for 100 yards, (and to be secured) that the back flood water may go over them, with stop gates at the high grounds to prevent the floods from making their way down the cut, and also at the head to prevent the river from flowing in till it goes over the marsh banks, &c., stop gates also to be placed at the cross bank between Henfall marsh and Heck Ings, and likewise between Heck Ings and Gowdale Intake; the following tunnels will be wanted for communicating drainages, viz. Haddesey marsh, Henfall drain, Heck Ing clough, and Gowdale marsh; proper bridges will also be placed to join the roads and communications to grounds; the principal will be to Haddesey marsh, Sherwood road, to the Ings,

Ings, Egbar ditto, Henfall ditto, Henfall road to Weeland, Heck lane to the Ings, and from Gowdale marsh to the Intake.

I have also examined the grounds on the north side of the river, and find a cut equally practicable there, and in some respects preferable, but being wholly through inclosed farms, I have caused the first survey to be made as above described, which will pass chiefly through the open Ings and marshes, and for the greatest part through grounds of very little value, being the separation between high grounds and the low; the whole length will be about three miles and three quarters.

Though I do not see an absolute necessity of extending the cut below Gowdale lodge clough, in order to procure the essentials of a navigation; yet as obstructions at present unforeseen may arise, it seems to me necessary that the undertakers should have a power of removing obstructions, and making horse towing-paths from the outfall of the river Aire into Ouse, to Gowdale lodge clough, as well as above.

Having now dispatched what seems most necessary respecting the river Aire, it remains to make the requisite observations upon the river Calder.

The most embarrassed part of this river, and the only one dependent on mills, is the cut from the warehouse to the lock. Were the mill at the tail of this cut to keep always a full head there would need little alteration, but as this is scarcely to be expected, the most practicable expedient is to dig the cut eighteen inches deeper, and to form a barrier as before mentioned, so that the mill cannot draw above eighteen inches within head. This however will not be perfect, as the withholding the water at the Soak mills at Wakefield, from whence alone this cut is supplied, will occasionally and temporarily stop the passage of this cut. The navigation therefore in order to make it complete to Wakefield should have a power either of filling the cut from Wakefield mill dam, or to purchase ground to make warehouses near the tail thereof, with a road to lead to them.

The dam boards at Castleford being preserved as at present, the whole pond from Penbank lock to the river Aire will have a sufficiency of water, a place called the Meer Round excepted, with some little places that may easily be helped near the tail of Penbank: the bottom of Penbank lock however lies too high by nearly a foot, and as it must therefore be rebuilt, the proprietors should have it in their power to rebuild it in a new place and lengthen the cut, so as to drop it into deep water about 100 yards lower, or to rebuild it in its present situation, as may ultimately appear most adviseable.

The

The dam boards of eleven inches being preserved and made to strike with ease, at Kirkthorpe Lake and Penbank dams, will make the necessary water from Wakefield lock to Penbank, except one shoal, called Holford, about a quarter of a mile below Kirkthorpe lock, which being a rocky scalp, I advise to be lowered by hand labour, rather than make any lengthenings in the cut of Kirkthorpe.

The Meer Round is a sandy shoal of no great extent: it is probable it may be helped by proper weirs, without making any new cuts, and hence we pass into the river Aire without further obstructions.

It is necessary to mention, that for the sake of preserving the course of the present navigation from Knottingley townside upwards, it will be proper to keep Knottingley lock in repair, and also for the sake of preserving the communication of Mr. Brandling's coal staith, it will be necessary to keep the Thwaite lock in repair; and in general where there is no particular objection, I would advise, that all the present locks be kept up, as by this means when any thing happens amiss with one lock, where there is a duplicate, the navigation can be carried on by the other while it is thoroughly and substantially repaired, nor will the mills lose any thing by a double leakage, as it will be very easy to keep the locks, where there are duplicates, in far better order than is practicable in the present state of business.

J. SMEATON.

Austhorpe, 28th December, 1771.

The REPORT of JOHN SMEATON, engineer, upon a view of the Calder navigation, the 25th and 26th Feb. 1779, in company with Messrs. Royd, Charlesworth, and Waterhouse, of the committee, and Mr. Walpole, agent.

RESPECTING matters of common repair, those having been pointed out on our passage up the river, I shall at present confine myself to such things as tend to improve the navigation, by removing those obstacles that length of time and experience have pointed out after successive repeated floods, of which the following seem to occasion the most frequent stoppages, and the most frequently need temporary helps.

1st. Horbury mill pasture cut head, now called the Broad cut head.

2d. The Long cut head, at Dewsbury.

3d. Batty's mill cut, tail and head.

4th. Kirklee's cut, head and dam.

5th. Tail of Anchorpit lock.

6th. Brighouse cut head and dam.

1st. BROAD CUT HEAD.

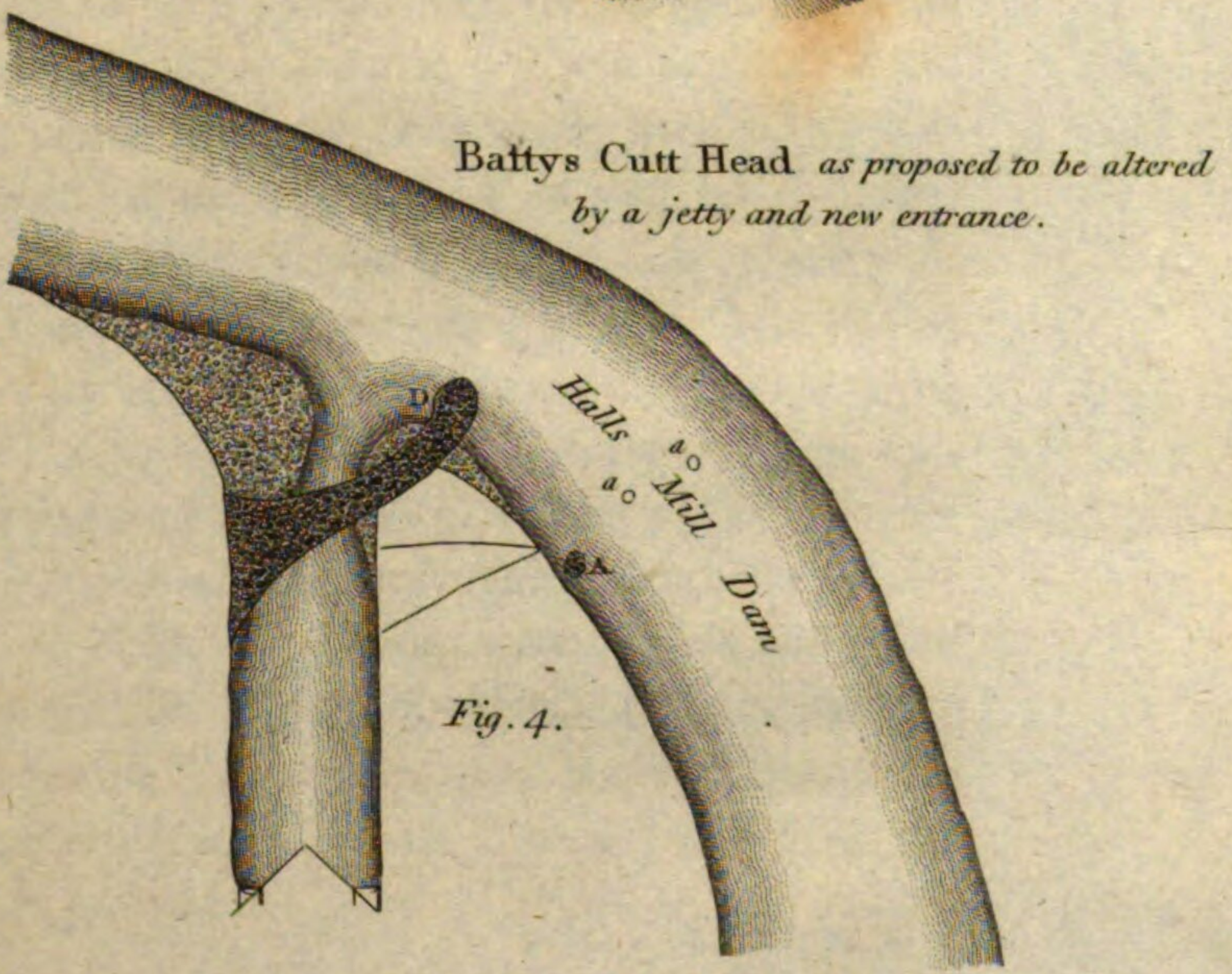
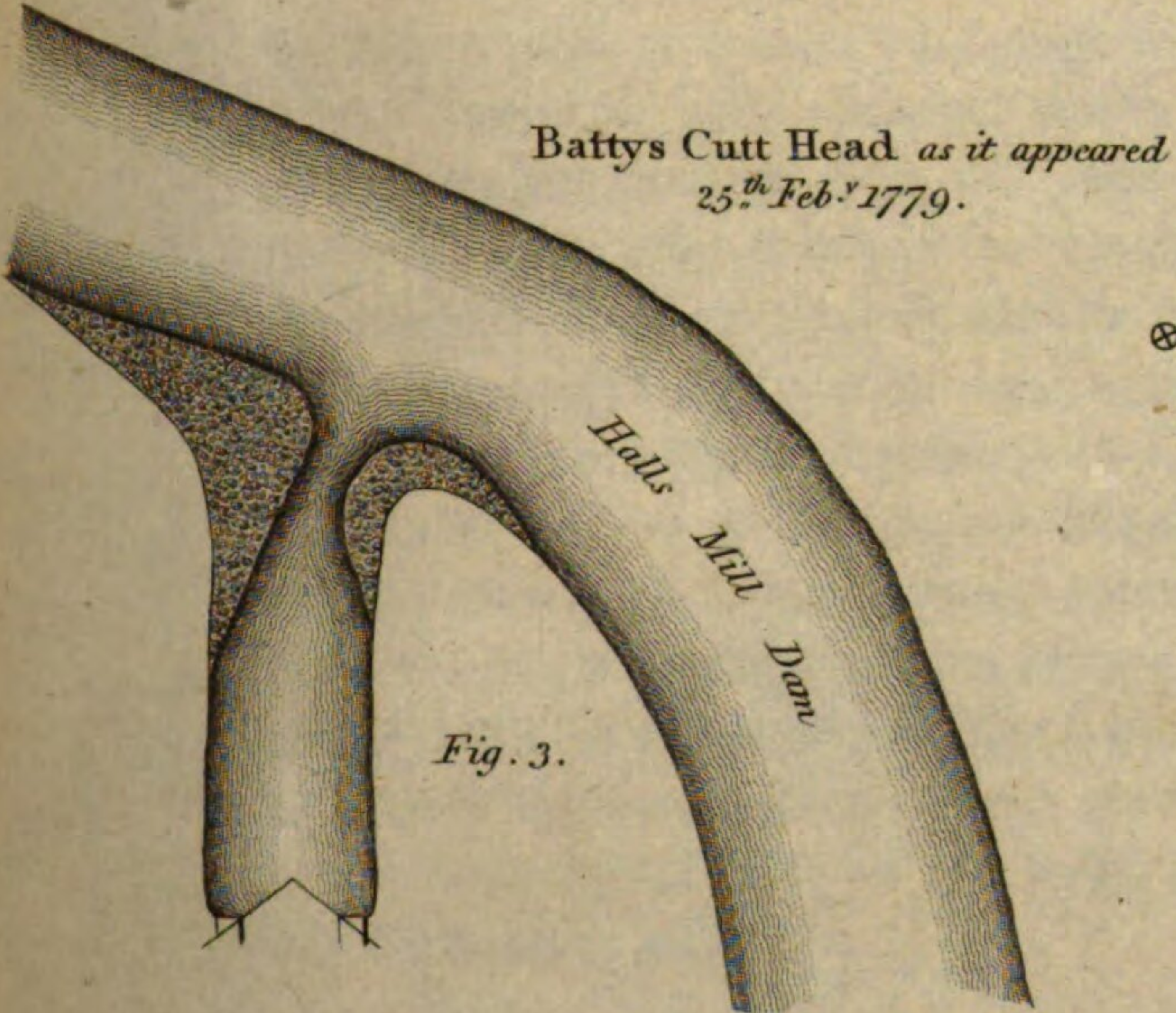
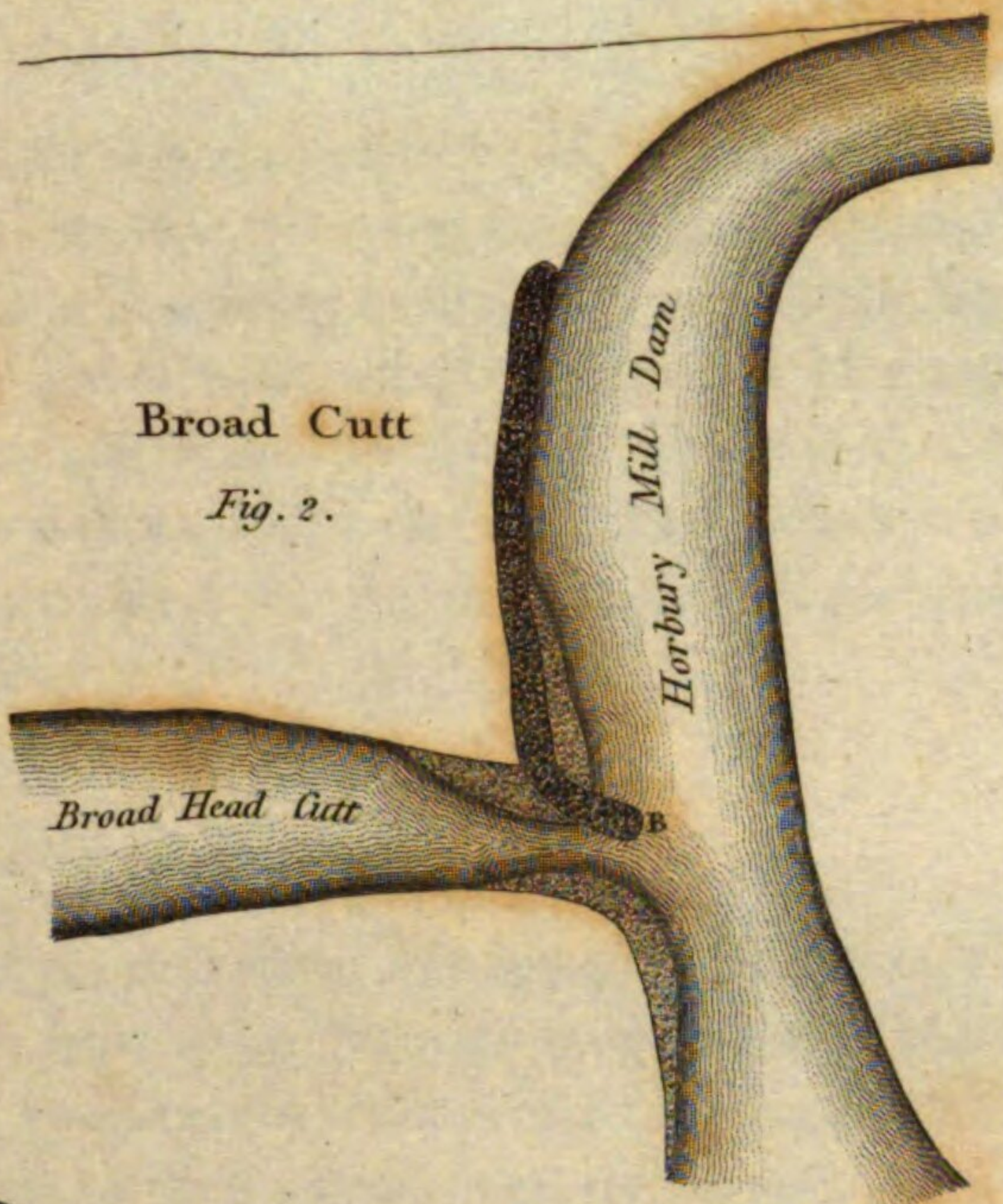
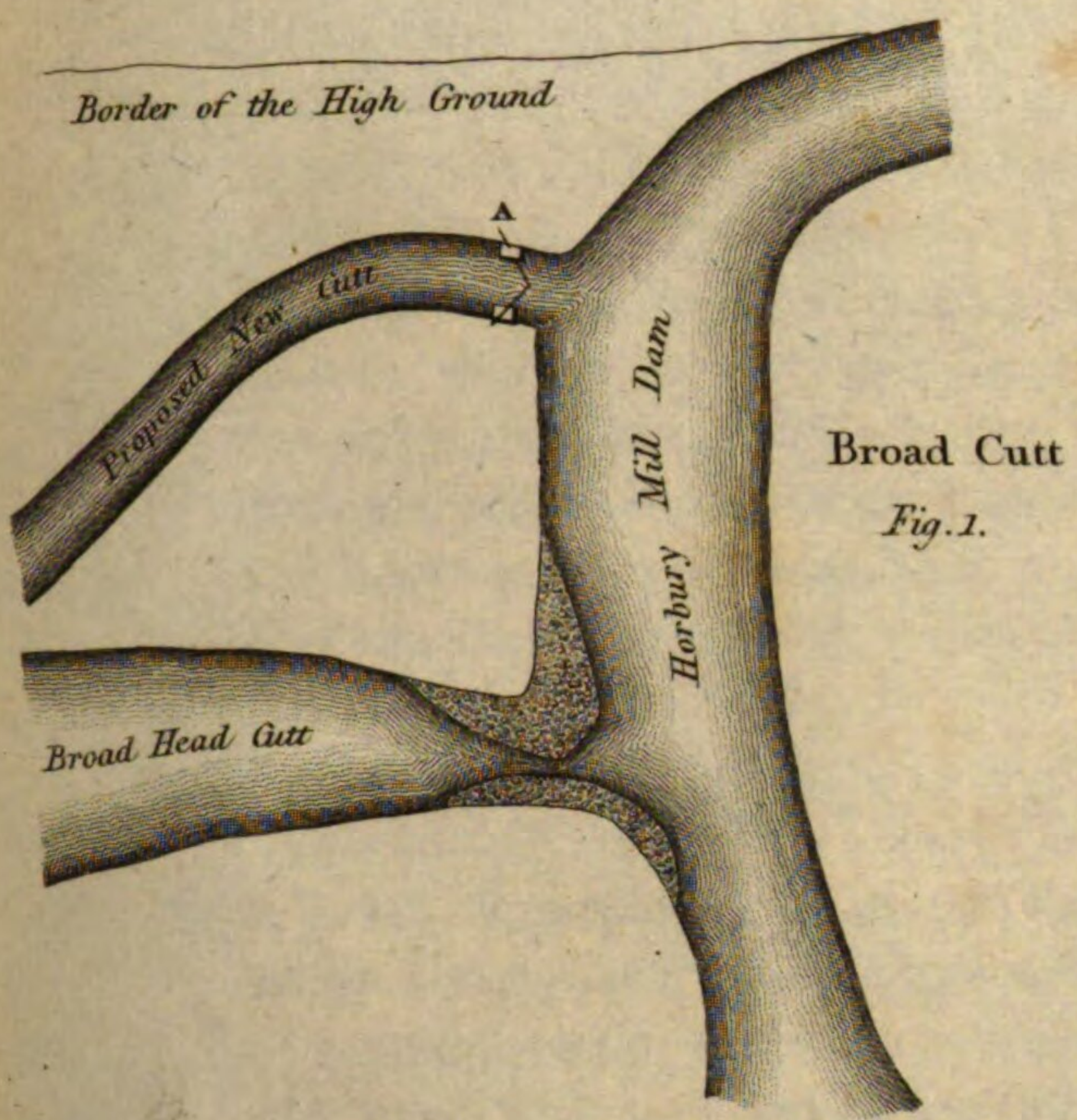
The head of this cut, from the gradual wearing away of the land by floods, has always been very subject to sand, therefore often required to be raked, and become very troublesome; there was once a rubble weir thrown in from the up-stream point, which seemed to answer very well, till the succeeding floods took away the land, leaving the weir disjointed, which then coming in the way of vessels, has been totally removed. The only complete remedy will be to make the entry from the cut from the deep water higher up, and as it appears from observations upon the whole river, that those cut heads preserve themselves best from sanding, whose upper point of land projects further into the stream of the river, than the lower point, this cut would best commence from the ground above broken by the floods making the projecting point, the upper side of the cut's

cut's entry, and this being preserved as it is, by being footed with rubble, the annexed sketch, plate 5. fig. 1. will give an idea of the alteration; it will be proper to leave a space between the south bank, and the foot of the high land, otherwise all the flood-water will be stopped from going that way: and to prevent the flood-water from going in at the new entry, and out again at the old one, and thereby hauling in sand and silt, it will be proper to put stop-gates upon the new cut head, at A; and lastly, as this new cut and works will be dug and founded below the level of the water of Horbury mill dam, with the water of which and Broad cut it will be in a great measure surrounded; therefore, unless a trench can be cut eastwards, under the high ground on the south, these works must be bottomed by artificial drainage, which, as it will be in an open gravel, will be very expensive. If, therefore, the execution of this scheme should be thought too expensive, I would propose, for trial, that contained in sketch, fig. 2, where, to prevent the lands going away any further, and thereby widening and filling up the river, I would begin to foot it up from the broken ground above, with a slope of rubble, and lastly carry out its lower end into the stream as is shewn at B, in the sketch, fig. 2, which being raised but a little above the common surface of the water will, as far as it reaches, in time of freshes and floods, act as a dam, and instead of a sand in its eddy, will make a deep, and thereby keep a channel open, and being carried out to a sufficient distance what matter goes round its end will be carried down the stream without being deposited, as it is now upon the eddy shore. Doubtless this will make the entrance more awkward, but any thing is better to a vessel than being caught by the bottom, and particularly in the dam of a mill, or to need being raked off after every flood and fresh: the original weir or jetty was constructed on this principle, but the ground not being footed up and secured for a length above it, it was washed away since my attendance, and the place left as before mentioned.

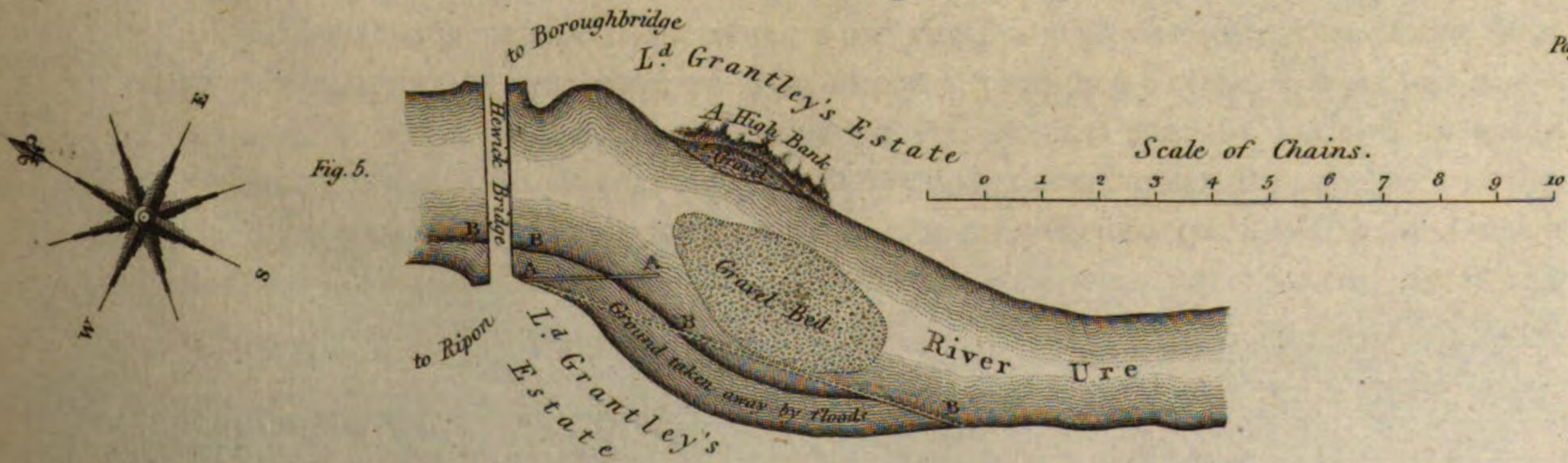
2d. THE LONG CUT HEAD.

This cut head needs frequent raking, and is more troublesome than it should be, though it opens into the navigation's own pen of water. I do not find that internally it is attended with much trouble, and as the down-stream point of the entry projects further out than the up-stream, I would recommend to try the effect of cutting and rounding off as much of the down-stream point, as can be done with safety, facing up the lower part of the new dug surface with rubble, to prevent the action of the floods upon a new surface, from taking away what may be prejudicial; and if the simply taking away from the down-stream point should not be sufficient, it may be further helped by being rendered more prominent by a rubble jetty from the up-stream point, somewhat

SKETCHES of the Improvements to be made on the RIVER CALDER.



A PLAN of HEWICK BRIDGE and part of the RIVER URE.



somewhat in the nature of that proposed for Broad cut head. If nothing of this kind should fully answer, an effectual cure can be made by a new cut following the skirt of the high land under Mr. Wilcock's house, and coming into the river a little higher than the opposite point of watergate lock; but as the navigation cannot now be stopped, the digging of the cut under level of the natural drainage, and the necessity of a very stout pair of flood-gates at the head, or rather a flood-lock, are considerations that in my opinion render it adviseable to try what effect will follow from the more simple methods above pointed out.

3d. BATTY'S MILL CUT TAIL AND HEAD.

In regard to the tail, which was sanded on this view, and is now liable to sand; it wants nothing but a low rubble weir or jetty from the up-stream point of the tail of the cut, exactly like that at Wakefield, which was constructed by my directions, and the cut's tail has never sanded since. It is very possible that the sharpness of the up-stream point of Batty's Tail might for years be preserved by a bush or root, a few rubble stones, or other accidental matter, which being now worn and taken away, may render it more liable to sand. A good deal of the upper part of this cut is rather shallow, but as what is below the upper gates may always be cleared at pleasure by drawing off the water, I shall not dwell upon it. The principal grievance is a great tendency of this cut's head to sand, so that it needs often raking, and seldom continues long quite free. This cut going both by Batty's and Hall's mill, its head opens into Hall mill dam, and as this dam continues good when vessels are fairly into it quite away to Cooper's bridge lock, with a good entry there, and as a new cut cannot be taken upwards to much more advantage, without being carried through ground to a considerable height, and where a new pair of stout flood-gates will be wanted, I would advise to attempt to remedy this entry, in a way somewhat similar to that proposed for the Broad cut head; because, exclusive of this single circumstance of its great tendency to sand, the rest can scarcely be better.

The sketch, fig. 3. which is merely done from memory, is supposed to represent the cut head, as it appeared sanded upon this view, and in the narrow of which there was but barely three feet water at dam's height, though every other part was unexceptional. In order to remedy this, I propose to cut a new entry, pointed square to the stream, as shewn in sketch, fig. 4, its up-stream side and point, defended by a rubble jetty, raised but a little above dam's height, that the water may fall over it, and which upon the same principle as laid down respecting the jetty or weir for the Broad cut head,

head, instead of a sand on its down-stream side, will produce a deep, and by projecting it a little into the river, will also produce a deep round its termination, and thereby continue a deep passage from the cut to the river. This again will doubtless render the entry more awkward; but the very best in every respect, and the cheapest are not always compatible in an artificial inland navigation. However, to render the entry more safe, in time of freshes, when alone in reality there can be any difficulty, I would advise a couple or three strong piles to be driven in the course of the river, as shewn in the sketch at *aa*, and that a very strong mooring-post be fixed upon the land at *A*, by which vessels may be lowered gradually down the stream, and by a cross rope from the vessel's head, swung into the cut before they quit their hold at *A*, and if in going up in a fresh they get fast to *A* before they go out, their getting out will be perfectly easy and safe, though there were to be no piles in the river at all.

4th. KIRKLEES CUT HEAD AND DAM, and

5th. THE TAIL OF ANCHOR PIT LOCK.

If Kirklees cut head were the only defective part, it would be worth while to try a remedy upon the same principles as the last, but as the dam itself is too shallow, in several places, which have grown worse rather than better of late years, in consequence of which frequent stoppages happen that require the reach above to be drawn down, which of course produces a loss of time and hindrance there, to wait for its filling; and as the tail of Anchorpit lock, though very good formerly, has become much obstructed by stones, &c. being brought down from the tail of the dam, and therein deposited; to remedy all these evils at once, I would propose to take a new cut out of the Anchorpit dam on the south side, and following the verge of the high ground to carry the level of Anchorpits dam water along, till near the flood-gates of Kirklee's cut, and there, by a new lock, to drop the vessels into Kirklee's cut, just below the present flood-gates; by this means the navigation by those mills will be rendered independent of them; a circumstance, I believe, very desirable to all parties.

A pair of flood gates will doubtless be required at the entry from the river into the new cut, but the land at this entry being bold, the placing of flood gates will be very convenient, and as the whole will be dug and founded, (the lock pit excepted) above the level of Kirklee's cut water, the expense will not be enhanced by artificial drainage, for the work being bottomed from the tail towards the head, the water will be drained by the cut, and nothing of the present passage disturbed till the new one is opened.

6th.

6th. BRIGHOUSE CUT HEAD AND DAM.

Since the flood-gates near the head of this cut were erected, that part of the cut across the low meadows from the flood-gates to the river, has become very subject to sand, which being of some length has become too troublesome. The river has also become more shallow between this cut head, and Lilland's lock tail since the breaches at Lilland's. Those evils will admit of a complete remedy only one way, that I can see, and that is, to carry the cut from the present flood-gates up the meadows, to a point nearly opposite to Lilland's lock tail, and to secure the water there by a catch dam, which will also render the navigation by Brighthouse independent of the mills, which is indeed very desirable.

Flood-gates at the head will certainly be needed, and the digging of the cut will require artificial drainage, but as the cut will be shallow, and I have hopes that the soil will not produce much water, and that this may be done at a moderate expense, as no new lock will be required; and by these means the navigation will be rendered independent of all the mills from Cooper's bridge lock to the head.

Above Lilland's nothing of moment occurs till we leave the river at Brook's mouth, and there the double lock is a very great evil, on account of its great consumption of water, at a place where it is most scarce, but as no alteration in it can take place for the present year, I shall reserve my opinion upon the particular mode of remedy, till a further opportunity, only intimating that the double lock should be converted into three single and detached locks, of which I expect that the uppermost may be converted so as to make one.

The runs in the Sowerby bridge cut should certainly be stopped the ensuing season. The mode of which being sufficiently pointed out and understood upon this view, it need not enter into this report.

J. SMEATON.

London, 22d March, 1779.

RIVER AIRE DRAINAGE.

The REPORT of JOHN SMEATON, engineer, upon the drainage of certain low grounds lying upon the river Aire, in the parish of Kildwick, from a view thereof, taken 31st May and 1st of June, 1764.

THE river Aire seems in general to run very dead, and in a remarkably meandering course in the neighbourhood of Kildwick, so that the lands lying thereupon, are much liable to floods in the winter season; but the lands which were the immediate object of this view were many of them under water, at the time of taking it, and the rest were so spoiled by the long continuance of the water upon them, that their value is greatly diminished, and all further improvements rendered difficult and precarious, without immediate help from drainage. I have also been informed, and my own observation agrees therewith, that these lands are now in a much worse state with respect to drainage, than they formerly were, insomuch that several parts are now below the level of the surface of the adjacent river, into which they drain, (when in its ordinary state) that formerly were above it, and then were firm and dry land. The evident cause of which alteration is as follows: On the south side of the river Aire, comes in a beck, which rising more immediately from among the hills in rainy seasons comes down with great rapidity, and in its course, washing the foot of certain cliffs, or beds of pebbles, gravel, and shingle, brings with it a great quantity thereof at such times, which matter being disturbed or moved by art, for the sake of washing or collecting such pebbles as are of the lime-stone kind, for the purpose of making lime, about two miles above the mouth of this beck, as I am informed, must of course greatly contribute to increase the quantity that otherwise would be brought down its course: the quantity of this matter already brought down is so great as to have in a manner filled up its own channel, so that for nearly a mile in crossing the plain, from the hills to the river, its bed is in general higher than the adjacent lands, the waters being confined between artificial banks; but these banks having been raised only occasionally, and by piecemeal, as the bed of the beck has grown higher, are in general too weak and slight to confine the waters in time of high-floods, so that the surface of the adjacent lands is covered with pebbles and gravel in many places, where it has been driven through the branches.

The

The channel of the river Aire is in this neighbourhood naturally deep ; but the great quantity of gravelly matter brought down by the beck above mentioned in the channel of the river, being carried downwards by the violence of the floods of the Air, in rainy seasons, has in a great manner filled up, or obstructed the channel of the river for half a mile below the mouth of the beck ; and it has been remarked, and, in my opinion, such an effect must naturally follow from such a cause, that the shingle above mentioned, travels every winter lower and lower in the river, as the quantity brought in increases, and at the same time near the mouth of the beck grows higher and higher, so that it raises the water in the river above these obstructions, in the manner of a dam, and at present pens it over the surface of several of the lands, to the great detriment of others with which it is almost on a level ; and as this evil has come on gradually increasing, it is probable that the surface of the river has gradually risen several feet within the compass of a moderate number of years, as is confirmed by persons now living, and, therefore, if some method be not taken for remedy thereof, in all probability it will grow to such a pitch as to render useless all the low grounds upon the river Aire, between the said beck and Coningley mill, unless the river should force itself a new course through the meadows below, as it probably will do (such instances being frequent) unless timely relieved by art.

As the effect of the aforesaid obstructions is to pen up the water of the river above the same in the manner of a mill-dam, which reaches nearly upon a dead level as far as Coningley mill, which I compute to be about three miles, by the course of the river ; the meadows on both sides lying low, are immediately put under water by a small rise of the river by rain. The meadow in going up the river towards Coningley mill gradually rises higher and higher above the surface of the river, as it was in the dry season, when I viewed it ; yet, as these lands lie further from the out-fall of their water, the water advances upon them in proportion to their distance, when it is raised by a flood, so as to make them equally liable to floods, though not of so long a continuance. The land lying on the south side of the river, between the aforesaid beck and Kildwick bridge, and for about a mile above the said bridge in the same side, seems most oppressed with water. On the north side, between the bridge and Coningley mill, something has been attempted by way of banking ; but as a great part of the embanked land was not at the time of this view above a foot higher than the surface of the river, and a good deal only a few inches, it follows, that though these banks may be of use in keeping out sudden and casual floods from spoiling their crop in summer, yet the continued floods in winter, as there will be no passage for the
waters

waters from the surface of the lands into the river through the tunnels, the river being then generally for a long time together higher than the surface of the lands, there can be no drainage, and consequently the banks will be of little use, as the land will be starved and impoverished by the continuance of the downfall and soakage water upon them; and as the quantity of shingle keeps increasing, and the surface of the river will be raised higher and higher, it is very probable, that in the course of a few years, the surface of the river will be higher than the surface of a great part of the said embanked land, in which case the partial drainage which they now enjoy will cease even in summer.

For a general remedy of the drainage of all the low lands that adjoin the river Aire on both sides, between the said beck and Coningley mill, I would recommend the making a new cut or river from that part of the river stagnated by the said obstruction, to a convenient part below them, by which means several feet of water may be drawn off from the said stagnated pool, and thereby the river, as well as the lands dependent hereupon, be put into their ancient course of drainage and improvement.

Having carefully viewed the course of the river from the commencement of the obstructions to the termination thereof, being in length about half a mile, there appears to me by estimation to be at least six if not eight or nine feet of fall. I did not take a level, because the time previous to the meeting of the gentlemen concerned would not allow it; but as there is an ample sufficiency of fall for the purpose, it is of less consequence what the level exactly is. Now it is evident, if there be six or even five feet of fall, that by a sufficient cut the water will be drawn off five or at least four feet below its present surface, and as the channel is in general six or seven feet deep above the obstructions, the water will reduce itself, in dry seasons, a proportionable quantity all the way as far as it pens upwards, that is near to Coningley mill, and, consequently, take off the surface waters from all the adjoining lands, as before asserted.

This cut I would not advise to be at a medium of less dimensions than as follows, viz. twenty feet bottom, forty-five feet top, and eight feet deep.

The proper place seems to me to be on the north side of the river, from or near the head of Mr. Richardson's corn farm, thence almost straight through the low end of his grass, turn thence through Mr. Baldwin's Garforth Ing, and thence through Mr. Baldwin's Holme, into the present course of the river, where grows a pretty remarkable clump of ash trees. This course being measured, was, in length, three furlongs and
twenty-three

twenty-three yards. A cut of the above dimensions, at 3*d.* per yard cubic, will come to £79. 9*s.* 6*d.* per furlong, and for three furlongs twenty-three yards £246. 14*s.* 8*d.* The land cut will be two roods twenty-nine perches per furlong, and therefore in the whole, two acres and eight perches. The land covered on each side will be nearly equal to the cut, which being supposed of half value, the damages to be paid for the cover will be equal to the value of the land for the cut; one bridge over the same will be wanted, which, if built of stone, may probably cost about £80.

A cut of the above dimensions will vent as much water as the old river, when the flood rises even with the grafs, but were it of ever so great dimensions, it cannot vent the water faster than it comes.

The old river I would advise to be kept open, as a receptacle for the shingle coming down from the beck: and as the old river will be less loaded with water in time of floods, it will afford a readier passage for the water of the beck; and the force of the current being less violent in the old river, will not drive down the shingle so fast into the river below the tail of the new cut. Hence I disapprove of cutting for the beck a new course into the river to a lower point; because, by giving it too much fall, it will bring down shingle the faster, and, by carrying it in at a lower point, the shingle so brought will sooner get down the river into the part now unobstructed; to do this would therefore be to destroy the whole for the sake of a part.

In case the scheme above proposed should meet with difficulty, a drainage from the lands in question may be obtained by bringing up a back drain from, or near the point above specified, between the river and the high land, and banking against the river. This may be done on both sides the river; in which case the drainage on the south side must be carried underneath the beck by a funken funnel or fox: this method may be practised with great convenience as far as the bridge, but yet is not obliged to terminate there, but may be carried forward through the low grounds on both sides, as far as necessary, towards Coningley mill. As it would greatly add to the expense to raise the banks sufficiently high to keep out the great winter's floods, and at the same time, as I apprehend, impoverish the lands for want thereof, I would advise not to raise the banks more than four feet above the low water's surface, laying them, where made new, very flat and sloping, and well sodded, that the water, in going over them, might not make a breach.

Something

Something might be done by way of clearing the old river, but to be in any degree effectual, must be at a much greater expense. The parts most requiring clearing, are those near the head of the shoal, that is near the mouth of the beck, which, of consequence, would be again the first filled up; upon this scheme it would therefore be adviseable to turn the beck to the tail of the shoal, because there is most room for the deposition of its contents, without immediately obstructing the parts supposed to be cleared; but as this would in consequence produce an obstruction still more extensive, a radical cure will be rendered still more difficult and expensive.

J. SMEATON.

Austhorpe, 26th July, 1764.

P. S. For the evils arising to the lands from the flooding of the beck, I see no lasting remedy; they arise not for want of fall, but rather by hewing too much, so that let whatever course be made for it, it will be liable to be choaked with gravel, unless the coming down of the gravel could be prevented; if this cannot be done than by enlarging its channel, and affording it room for the deposition of its contents, it may be effected by raising and strengthening its banks, partly with the matter lodged therein, and faced up next the channel with new earth from behind to give it room, by raising a fresh bank parallel with its eastern one, at forty or fifty feet distance, taking the matter from between the banks to make the new one, which will, in some measure, make a new channel, letting the beck have both the old and new course to range in time of floods.

RIVER AIRE CANAL.

The REPORT of JOHN SMEATON, engineer, upon the plan and projection of a canal on the north side of the river Aire, from Haddlesey to a place called Brier-lane End, in the township of Newlands, as laid down by Mr. JESSOP, engineer.

IN my report of the 29th Dec. 1771, upon the improvements of the navigation of the rivers Aire and Calder, from the towns of Leeds and Wakefield, to the free and open tides way, after setting forth the practicability and utility of a canal to be made on the south side of the river Aire, from Haddlesey to Gowdale Lodge Clough, and that it would be the means of making a communication free and open at high water in the shortest tides and driest seasons, between the upper parts of the river and the lower, without the use of flashes. I further mentioned, that having also examined the grounds on the north side of the river, I had found that a cut on that side would be equally practicable, and in some respects preferable, to that on the south, but which was not further pursued at that time, for the reasons therein set forth. The application to parliament being postponed to another session, having given opportunity to the proprietors of the rivers Aire and Calder, further to consider the utility that a canal on the north side of the river would be to them, and how the ground on that side would be affected thereby; they again applied to me for that purpose, but being myself altogether otherwise engaged the past summer, I recommended Mr. Jessop to make the necessary surveys, plans, and projection, which being produced, at the further request of the said proprietors I have taken a view of the line of the canal, as proposed by Mr. Jessop, and having also examined his plan, report, and estimate, I am of opinion, with Mr. Jessop, as follows:

1st. That by extending a canal from Haddlesey dam head to the river Aire, at or near a place called Brier-lane End, in the township of Newlands, being in length about $7\frac{1}{4}$ miles, the communication between the upper part of the river and Armin, will not only be shortened considerably more than by a passage from the said dam to Gowdale Lodge Clough, before proposed on the south side, but will be attended with this further great convenience to trade; that whereas by the Gowdale canal, there would, in dry seasons and short tides, be a navigable communication only at high water; by the present plan, there will be a navigable communication between the upper parts of the river and

and Armin, at all times, except at low water in dry seasons, which would very often be a saving of twelve hours in the passage.

2dly. That by raising the south bank of the canal so as to be flood proof, all the great tract of low grounds, lying to the north of the canal, will be entirely embanked and defended from the floods of the river Aire, arising from breach of banks in that long tract of river between Haddlesey and Brier-lane End, being by the course of the river at least $12\frac{1}{2}$ miles; and that, though the water being confined upon the lands on the south-side of the canal may, in some smaller over-flowings, increase to a greater depth; yet, in the great over-flowings of the river, as the water can never rise higher upon the lands than the water in that part of the river from whence it proceeds, there then can be no great difference, and in all cases, as there will be a less extensive body of water to be discharged, it will be much sooner discharged by its out-falls, which, in drainage, is of the greatest importance, as the waters standing long upon the grounds do more damage than can arise merely from the depth of it.

3dly. That the drainage of the whole country neighbouring upon the canal, will be greatly mended, for as the surface of the canal will not be liable to rise and fall like the river, being defended by gates at each end, all these grounds that lie higher than the surface of the canal will drain immediately into the canal, and all those grounds whose surface lies even with or below the level of the canal, will drain into the back drains that must, of necessity, be cut behind the banks, which, by conducting the water from the surface of the adjacent country, by the most ready passage, to the main drains of the respective out-falls, will be a great means of improving the present drainage, and as there will be capacious tunnels under the canal, where it intersects such drains with stop doors upon the tunnels, to prevent the waters reverting where necessary; this advantage will operate equally on either side.

4thly. That the above means will put the drainage upon a better footing than it is at present, which is sufficient for a scheme of navigation; yet, as the canal is proposed to be embanked flood proof on both sides, between Newland's bank and the out-fall at Brier-lane End, the drainage of Carlton might be improved by running off a part of their top waters by a sluice into this part of the canal, and yet Newland's fully defended by the said stop-gates proposed at Newland's bank, and which, at any rate, will be a proper security.

Upon

Upon the whole, I see no objection to this design of Mr. Jeffop's, but what would be made to a canal passing in any line through this country: on the contrary, I think it well adapted to answer the end, and to avoid the severing of properties as much as possible.

Respecting Mr. Jeffop's estimate, I beg leave to observe, that the longer I live, I every year see more into the reasons why estimates are generally exceeded in the execution, and how impossible it is, without repeated proofs from experience, to conceive how this can happen in so great a degree; I therefore do not wonder, that he has come considerably below the prices in the articles of construction, that I should esteem it necessary, he not having had an opportunity of having recourse to my estimate for the performing of the Gowdale canal, which is similar to this, but which now being put into his hands, he will be enabled to re-model his estimate according to the prices thereof. Indeed, respecting the article of land, I have done nothing more than give the quantity of acres, cut and covered, as I apprehend that no engineer should venture to name a price for it.

J. SMEATON.

Austhorpe, 5th December, 1772.

RIVER LEA NAVIGATION.

AT a meeting of the trustees for the river Lea, at the Bull Inn at Ware, on
Wednesday, the sixteenth day of July, 1766.

PRESENT,

Thomas Dimisdale, M. D.	John Ives Gopp, Esq.
Thomas Pleemer Hyde, Esq.	Mr. Thomas Srolt.
John Calvert, Esq. M. P. for Hertford.	Abraham Hume, Esq.
John Jenkinson, Esq.	William Cowper, Esq.
John Rowley, Esq.	Samuel Atkinson, Esq. Mayor of Hertford.
Thomas Walton, Esq.	Paul Field, Esq.
Timothy Caswell, Esq.	Richard Dickinson, Esq.

ORDERED, That Mr. John Smeaton shall forthwith take a survey of the river Lea, and make a plan and estimation of the best method of making a navigation from Hertford to the river Thames, and that Mr. Thomas Yeoman shall assist him therein, and that Mr. Smeaton make a report thereof to the trustees on or before the twenty-ninth day of September next, and Mr. Smeaton is desired to be as particular as he can in the description of such parts of the course of the said intended navigation, where he shall be of opinion that new cuts ought to be made, and what effect such new cuts will have upon the lands they shall respectively pass through, and the mill and other estates adjacent.

Examined by me,

HENRY THOROWGOOD,

Clerk to the trustees,

The REPORT of JOHN SMEATON, engineer, upon the new making and completing the navigation of the river Lea, from the river Thames, through Stanstead and Ware to the town of Hertford.

THE present navigation of the river Lea, above the tides way, being in all probability formed upon such expedients as occurred before the invention of locks, or pen-luices, with double pairs of gates, is now, when compared with the modern improvements in navigation, become very defective, notwithstanding many attempts to improve upon its present principle, which is that of pens and flashes from eighteen weirs and turnpikes; besides a cistern or lock properly so called at Ware mill; and the lock at Bromley improperly so called, having only single gates for penning in the tide, through which the vessels navigate in tide of flood, or about the time of high water, these, with a cistern or lock occasionally used at Hackney water-works (lately erected) are the present means of navigation through a course of river of more than thirty-one miles from Bromley lock to Hertford, and having 111 feet fall or thereabouts, as appears from a survey and level of the river, which seems to have been very well taken near thirty years ago.

In the month of July, 1766, having, with the assistance of Mr. Thomas Yeoman, engineer, and by order of the trustees for maintaining and improving the said navigation, carefully taken a view with many observations on the present state of the river and navigation thereof, and having compared the same with the old plan before mentioned, I herewith present the trustees with a new plan of the said river, with three schemes for completing or improving the navigation thereupon. The first containing every improvement that in point of expense I would recommend; the second containing the most frugal scheme that I can recommend; the third is a medium between the two extremes, and which, upon the whole, seems the most eligible; the whole is founded upon these general principles:

1st. To do no damage to the adjacent lands; after the lands required for the works, and temporary damages in constructing them are paid for.

2d. To do no damage to the mills by diverting their water; and to preserve to them the several navigations in their own mill-streams that they now have.

3d. As

3d. As much as possible to prevent the mills from injuring the navigation, by drawing down their ponds.

4th. To make a safe and certain navigation in the dryest seasons with three feet water in the general, and at least two feet six inches in the shoals of the river and fording places made across the cuts.

To execute this scheme I propose

1st. To keep the river where it is tolerably straight, and sufficiently deep, for a length of course together.

2dly. To join those deep cuts and canals with locks thereupon, whereby the vessels will be enabled to pass from one deep to another without any flashes.

3dly. To make use of such of the old weirs or turnpikes as will be necessary for keeping up a constant body of water in the cuts and canals, in no case to pen higher than those weirs or turnpikes do at present; but in general not within four or six inches of the present height, and if it shall appear that any damage is done to the grounds by keeping up the necessary body of water in dry seasons, to embank the river in such places, and make back drains to carry off the soakage water into the pool next below, at all other times, as there will be a sufficiency of natural depth of water, the gates of the weirs and turnpikes to be drawn, in order that the river may have its free passage as at present. N. B. Three or four men that will be necessary to see that no damage is done to the locks and cuts, will also draw the gates as aforesaid.

4th. To navigate by the flow of the tides hitherto, till the barges are past the falling in of Hackney brooks.

Advantages of these maxims.

From hence the mills will receive great advantage from no water being wasted in flashes, which not only greatly diminish their heads but obstruct them by tail water.

The lands will also be benefited by not being liable to an uncertain pen of water.

The navigation will be not only improved by being rendered certain at all times, except in frosts and extraordinary floods, and by the shortening the distance, but by navigating

vigating in more still water, and in the straighter courses much labour in towing will be saved, and will be rendered so expeditious, that a vessel at moderate work will make her way upwards at the rate of two miles per hour, passing the locks included; that is, from Bow bridge to Hertford in about thirteen hours.—Hence the ruin of horses straining of barges, and great wear and tear of the tackle will be saved, as well as greater expedition be secured.

The different schemes referred to, with the separate expenses of the divisions thereof, will be sufficiently explained and compared by inspection of the three abstracts, and the particulars of each division will be had by inspecting the two estimates of the different parts.

It is to be noted, that nothing is to be supposed as proper matter of my estimate, save what is contained in each abstract previous to the double line; the value of lands and weirs is thrown in, in order to make a comparison of the different methods; which will again turn out somewhat different, according to the different values that are put upon them in the opinion of different persons, and that no conclusion may be drawn from the values that I have placed to weirs, turnpikes, and cistern lock at Ware, I have mixed the uncertain value of repairs that will be wanted to each therewith.

As I have endeavoured to settle the land-marks or principal stamina of this undertaking, I am well assured that what remains (which could not be done before) will be properly enquired into and represented by Mr. Yeoman, that is, if any of the three or any part of the three schemes are thought proper to be carried into execution. It will now be proper that Mr. Yeoman be employed to look over the grounds where the works relative to such scheme are to be, and as he is a judge thereof, which I am not, to take notice of the probable value; as also how, by any deviations from the lines I have drawn for the cuts and canals, the divisions of properties may, as much as possible, be avoided; and in case any other way than what is pitched upon on the first face of the thing shall seem more proper on re-inspection, to make report thereof, with such other matters as shall be directed, or shall occur to him, by which means the trustees will have the whole matter fully and clearly before them.

I furthermore desire, that what I have set down in the abstracts, under the title of expence of the works, is to be considered as so much hard money, without defalcation on account of the charge of this scheme, the act of parliament, the interest of money,
or

or any salary or gratuities that may be thought necessary to the principal director or directors, or the clerk or clerks of the works.

It perhaps will be wondered why, in my third scheme, I have not preferred the keeping of that part of Enfield mill-stream, contained in the second? my reason is, that as that mill-stream is at present fed by a limited quantity of water, and millers are perpetually over drawing their supplies, in dry seasons the navigation would frequently be interrupted thereby.

I also entirely reject the new cistern lock at Hackney as part of my scheme, as neither its floor nor the river below is deep enough for navigation, without flashes there, as at present.

On inspection of the plan, it seems very desirable that a cut should be carried from the four mill pond at Bromley to the Thames at Limehouse hole, and which, from a general knowledge of the ground, I believe very practicable; yet, as this thought did not occur to me till I was compiling the plan, I must refer the gentlemen to Mr. Yeoman's report thereupon, to whom the same thought has occurred, and who has viewed and levelled the same, and which I shall inspect when I go up to town if thought eligible.

If the navigation below Bromley is thought proper to be continued through Bow Creek as at present, it will be proper to have a power in the act to lay Bromley lock lower, whenever it shall need a thorough repair, and make it with two pair of gates.

The following estimates are founded upon the suppositions, that the ordinary size of the cuts and canals are a sixteen-feet bottom, with batter, as one to one on each side, and to be three feet deep of water, but to allow for passing places, four at least in a mile, making fords and extra depth of ground where it lies considerably higher than the water; they are calculated upon a mean width of eighteen-feet bottom, and $4\frac{1}{2}$ feet deep, and to be done at $2\frac{1}{2}d.$ per cubic yard, drainage of water, where necessary, included; on these principles the cuts will be made for £27 10s. per furlong, and each furlong will, at a chain broad, including banks and back drains, contain one acre per furlong.

The

The locks to be made fit for the Ware barges at £100 per foot perpendicular, the extra charge of lock pits and drainage of water further included.

I have supposed all the weirs, with the cistern lock, to be private property; all the turnpikes belonging to the navigation; and that Archer's weir must be purchased, in order to be removed; if I have mistaken in that point, my mistake therein can easily be corrected.

J. SMEATON.

Austhorpe, 24th September, 1766.

An ESTIMATE for making navigable the river Lea, by such cuts and canals as were approved of by the trustees of the said river upon their inspection of the same, from Bow bridge to the present place of delivery at Hertford.

By JOHN SMEATON, engineer.

From Bow bridge to Lea bridge, inclusive.

	£	s.	d.
To clearing a shoal just above Bow bridge, called Bow Bridge Hill	150	0	0
To clearing two fords below Old Ford dock	50	0	0
To two miles of canal, which, at 3d. per yard, and with the dimensions specified in Mr. Smeaton's report, comes to £33 per furlong, and for two miles	528	0	0
To two locks penning 4 1 each	820	0	0
To two tail bridges to ditto	30	0	0
To bridge and flood-gates at the head of the cut	120	0	0
To making five fords for communication across the canal, which, including bridges, is at the rate of four passages per mile, at £10 each	40	0	0
	<u>1688</u>	<u>0</u>	<u>0</u>

To be purchased for this work, land sixteen acres

From Lea bridge to Newman's weir, inclusive.

To cutting two loops of the river Lea, between Lea bridge and Hildyard's turnpike	30	0	0
To five miles and an half of canal, exclusive of Enfield mill-stream, at £33 per furlong	1452	0	0
To scowering Enfield-mill stream, with contingents thereon	330	0	0
To lockage upon this canal 33 4 perpendicular	3333	0	0
Carry forward	5145	0	0

* The sum of 1688 l. is wrong, but it was so delivered in.

	£	s.	d.
Brought forward	5145	0	0
To seven tail bridges, at £15 each	105	0	0
To a road bridge, answerable to Hildyard's turnpike	80	0	0
To three large tunnels for the principal drains across, at £200 each	600	0	0
To nineteen fording places, at £10 each	190	0	0
To altering bridges, and erecting a stanch for regulating the water in the mill-stream	600	0	0
To extra expenses in continuing the navigation to Stewardson mill, by erecting a lock, and making a cut from the canal to the river	500	0	0
To ditto, on account of ditto, in making a stop in the river below the going out of Stewardson's mill-stream, and in the erecting gates for the continuance of the navigation	500	0	0
	<u>£7720</u>	<u>0</u>	<u>0</u>

Land to be purchased for this work thirty-six acres.

From Newman's weir to, and including King's weir.

To digging one mile and three furlongs of canal, at £33	825	0	0
To four locks, penning twenty-one feet	2100	0	0
To three tail bridges to ditto, at £15	45	0	0
To a road bridge to Waltham Abbey	90	0	0
To one ditto, answerable to Hollifield bridge	70	0	0
To one aqueduct bridge over the Cheshunt mill-stream	200	0	0
To three large tunnels for draining, under the canal, at £150	450	0	0
To a bridge and flood-gates at the head of the cut	120	0	0
To eight fording places, at £10 each	80	0	0
	<u>£3980</u>	<u>0</u>	<u>0</u>

Wanted for this work twenty-five acres of land.

From King's weir to, and including Carthagea turnpike.

To a cut, one furlong seven-tenths, past Carthagea turnpike	56	2	0
To a lock, penning three feet	300	0	0
A tail bridge	15	0	0
	<u>£371</u>	<u>2</u>	<u>0</u>

Wanted to purchase one acre seven-tenths of land.

From

From Carthagera to, and including, new turnpike.

	£	s.	d.
To a cut by new turnpike, three furlongs in length	-	99	0 0
To a lock, penning five feet	-	500	0 0
To a road bridge, answerable to new turnpike bridge	-	80	0 0
To clearing a shoal between the two turnpikes	-	85	0 0
To a tail-bridge over the lock	-	15	0 0
		£779	0 0

Land to be purchased for this work, three acres.

From new turnpike to, and including, Field's weir.

To a cut at Field's weir eight-tenths of a furlong	-	26	8 0
To a lock, penning three feet nine inches	-	375	0 0
To a tail bridge to ditto	-	15	0 0
		£416	8 0

Land to be purchased, eight-tenths of an acre.

From field's weir to, and including, Ware weir.

To clearing a shoal below Standstead bridge	-	100	0 0
To a cut from above Stanstead bridge to Ware weir, being one mile six furlongs and two-tenths	-	468	12 0
To three locks, penning eleven feet six inches	-	1150	0 0
To three tail bridges	-	45	0 0
To four fords	-	40	0 0
		£1803	12 0

To be purchased for this work, fourteen acres and two-tenths of land.

From Ware weir to, and including, Ware mill.

To a cut, three furlongs, by a new passage, into Ware mill head	-	99	0 0
To a lock, penning eight feet eight inches	-	866	13 0
To a tail bridge	-	15	0 0
To a ford	-	10	0 0
		£990	13 0

To be purchased for this work, three acres of land.

From Ware mill to the present delivering place at Hertford.

	£	s.	d.
To clearing a shoal near the balance engine	-	150	0 0
To a cut from the elbow above Fordham's mill into Dicker mill head, five furlongs	-	165	0 0
To a lock, penning seven feet six inches	-	750	0 0
To a tail bridge to ditto	-	15	0 0
To a road bridge to the mill	-	80	0 0
To three fords	-	30	0 0
To deepening Dick's mill-head, proper for navigation	-	99	0 0
To altering bridges and other conveniences	-	180	0 0
	£1469	0	0

To this work, wanted five acres of land.

GENERAL ESTIMATE for new making and completing the navigation of the river Lea from Bow bridge to the delivering place at Hertford, by such canals as have been approved by the trustees on their inspection of the same; by JOHN SMEATON, engineer.

Divisions of the River	Canal	River	Total length	Locks		Expense of the works	Acres of land
				No.	Rise		
From Bow bridge to Lea bridge inclusive	M. F. 2	I. 0	M. F. 2	2	F. 8	I. 2	£ 1688 0 16 0
From Lea bridge to and including Newnan's weir	5	6	0	0	5	7	77 0 36 0
From Newnan's weir to and including King's weir	3	1	0	1	1	4	3980 0 25 0
From King's weir to and including Carthagea turnpike	0	1	7	1	4	0	371 2 1 7
From Carthagea turnpike to and including New turnpike	0	3	0	0	3	0	779 0 3 0
From New turnpike to and including Field's weir	0	0	8	0	6	5	416 8 0 8
From Field's weir to and including Ware weir	1	6	2	2	1	6	1803 12 14 2
From Ware weir to and including Ware mill	0	3	0	0	4	8	990 13 3 0
From Ware mill to the delivering place at Hertford	1	0	0	1	7	6	1469 0 5 0
Distance from Bromley lock to Bow bridge	14	5	7	10	3	4	25 1 1 21 101 11 19217 15 104 7
To making towing-paths, bridges, gates, and stiles, at £20 per mile	-	-	-	-	-	-	512 0
To repairing six weirs and turnpikes, to be kept up for the use of the navigation, at £200 each	-	-	-	-	-	-	1200 0
Add £10 per cent. upon the works for contingent expenses, and upon the lands for temporary damages	-	-	-	-	-	-	20929 15
	-	-	-	-	-	-	2093 0
	-	-	-	-	-	-	23022 15
	-	-	-	-	-	-	115 1

N. B. In this estimate there is nothing included in the above for surveyors', or clerks' salaries.

London, 26th February, 1767.

J. SMEATON.

NEW RIVER WORKS.

The REPORT of JOHN SMEATON, engineer, upon the improvements making by the New River Company, near Ware, in the county of Hertford.

AT the desire of Mr. Walton, on Saturday, the 21st April, 1781, I viewed the works of the New River Company made and carrying on near Ware, and made such remarks thereon, as appeared to me necessary to give an answer to the question proposed to me, viz. In what manner, and how far the alterations and enlargements that the New River Company are now making in the New River, near Ware, have a tendency to affect the mills and navigation upon the river Lea below Ware?

To answer this question distinctly, I must in the first place observe, that subsequent to all outlets for waste water to return from the company's works and streams back again into the river Lea, there is a square open tunnel of stone, through which the water passes, and is called the gage. I had not access to take the measures with exactness, but was informed it was fourteen feet in length, six feet in width, and two feet in depth. Now, if the surface of the water below the gage were of equal height, or perfectly level with the surface of the water above the gage, the water would then remain stagnant, and none would run through the gage; but if the surface of the water above the gage be but a small, and even imperceptible difference, higher than the surface of the water below the gage, this difference forming a declivity, will cause the water to run towards the lower part, and the velocity or speed wherewith it will run will have a certain relation to the measure of this declivity; the quantity of water therefore taken or passing through the gage in a given time, will be proportioned to the velocity wherewith it passes. In order, therefore, that this construction called the gage may be really and truly such, or measure of a certain given quantity of water flowing through per minute, per hour, or per day, these conditions are necessary, first, that the surface of the water should be kept at a certain constant given height before it enters the gage, and at another constant certain given height after it has passed it, so that there may be a constant and equal declivity of fall from the water's surface above the gage to the water's surface below, and thereby also occupying the tunnel with the same degree of fulness: for if either the surface of the water above the tunnel be raised, while the surface of the water below remains at the same height, or the surface of the water below the tunnel be lowered,

that

that of the water above still remaining at the same height; in either case, the declivity or fall from surface to surface being greater, its velocity will increase in a certain proportion, and consequently the quantity of water drawn through the gage in a given time will increase in the same proportion; and the same thing will happen if the surfaces of the water above and below the gage are both raised, but that above more than that below, so as to form a greater declivity or fall; for by whatever means a greater fall is produced, a greater velocity and discharge will ensue.

Something appears to have been attempted towards a regulation of the water's surface above the gage, but nothing appeared to me to have been done with that view below the gage; however, while the capacity of the river below the gage remains the same, its capacity to convey water will remain nearly the same also, and this will in some measure prove a regulation to the height of the surface of the water below the gage; but if below the gage in several reaches, impediments, and obstructions to the motion of the current are removed, which will also be the consequence of widening or deepening, or both, so as to increase the section of the river, the natural consequence will be, that a given quantity of water will be run off as discharged at a lower surface, and if the discharge of water at the gage were entirely limited by a sluice gate, or otherwise, to a certain given quantity, the surface of the water below the gage would by this means be actually lowered considerably; but the moment the surface of the water below the gage is in any degree lowered, the tunnel of the gage being open, a greater quantity will issue in consequence of a greater declivity or fall, which, in consequence, will in part keep up the surface below to a higher pitch than it would have been, had the quantity been actually limited; that is to say, the effects of removing obstructions are in part that of creating a greater declivity at the gage, and in part, that of conveying away a greater quantity thus drawn through the gage in consequence of that greater declivity: it therefore appears to me very evident, that however laudable it may be, and is, in the New River Company to improve the water passage, considered as an aqueduct, yet the effects of widening, deepening, cleansing, and removing obstructions to the water's passage, have a direct tendency to create a greater declivity at the gage, and thereby to draw down a greater quantity of water from the river Lea, even supposing the water's surface above the gage to be kept to a regular height, which does not appear to me to be always the case, because there do not seem to me sufficient means of doing it.

I have intimated before, that the regulation of the water's height above the gage has been attempted, but this does not appear to me done in such a way as sufficiently to
answer

answer the end. The stream of water in passing from the river Lea to the gage passes by an over-fall, or tumbling bay, which seems intended to let the waste water go back again into the river Lea, when the surface is above a certain height upon the gage: but this over-fall can by no means fully and accurately answer the end, as being very much too short and confined: when I was there, about one inch of water was cascading over it, so that if the crown of this tumbling bay be the proper height for the water above, or before it enters the gage, the surface was then one inch above its proper height, and what effect this may have will be seen hereafter. But this is not all, for I observed a fresh water mark $2\frac{1}{2}$ inches higher than the surface then was, at which height the water had been, in my opinion, sometime in the morning of the same day; and when the water's surface was at that mark, there would have been at or about $3\frac{1}{2}$ inches water over the tumbling bay, and consequently near upon the same quantity, that is, above three inches, too much water upon the upper side, or above the gage.

The water brought down to the works proceeds originally from the river Lea, where there is constructed a piece of machinery called the balance engine, which, if kept in complete order, accurately adjusted, and left untouched, might be a great means of keeping the water at the gage more nearly to a just height above it; but from the very great difference in the admission of the water there in the morning and noon of the same day, it must follow, either that the balance-engine is much out of order and adjustment, or that the company's servants, in whose power it is left, had drawn there an occasional quantity of water; and if the latter, of whatever use it may be to the company, it cannot be considered, while in the power of their servants, as of any use towards a regulation of the water between the proprietors of water upon the river Lea and the New River Company.

The reasoning upon the matters above stated will equally hold, whether the quantity be ten cube feet, or a thousand; it therefore now comes in course to give you some idea of the quantity by which the stream of the river Lea may be lessened by the operations above mentioned to the mill-owners and navigation. To do this, however, with accuracy and precision, would require more observations and measures than can be taken in one day; but yet, what may be deduced from what I have seen and observed, may be sufficient to enable you to judge of the ground you stand upon, and whether an examination more in the detail be necessary.

When I was there, the difference, fall, or declivity at the gage, between the surface of the water above and the surface below the gage, I judged to be about an inch, or rather

rather better; supposing the difference to be one inch, according to my computation this difference would produce a discharge (from the measures of the gage before stated) of 1100 cube feet of water per minute, that is, above thirty tons, and nearly equal to the water expended by one of Mr. Walton's best mills, carrying two pair of stones, and would fill a cistern lock of a middling fall in about five minutes.

Now, if the difference were four inches, the discharge would be nearly double, and if the difference or fall were fourteen inches (which I apprehend it is very practicable to procure by a fuitable alteration of the New River), the quantity discharged would then be near upon the greatest possible, through that gage, viz. 3800 cube feet per minute. I would not, however, be understood, that when the water was above three inches higher than it should have been, that there was a quantity discharged due to a fall of three inches; because, for reasons already given, an increased discharge at the gage would raise the water below, and diminish the fall, so that it is probable, the true difference of fall was never more than two inches, in which case, the discharge would be above 1500 feet per minute; but which, by fuitable alterations in the river below, may be carried (as already mentioned) as far as 3800 cube feet.

J. SMEATON.

London, 3d May, 1781.

To the trustees of the river Lea.

GENTLEMEN,

WHEN I attended you at Ware, at your meeting of the 21st May, by order of Mr. Walton, for the purpose of explaining to you such matters as might arise from a consideration of my report made to him of the 3d May, which contained my opinion of the tendency of the improvements making by the New River Company, near Ware, a copy of which report he had caused to be communicated to you; it was, among other things, observed by you, gentlemen, on your view, that since it appeared that the surface of the water, in passing the stone gage, was lower with respect to the roof of the tunnel of the said gage, than it was with respect to the top of the two flat stones placed as marks, and referred to in the act of parliament, that therefore the tunnel of the gage was placed too high by the difference. To this I observed, that it did appear to me as if the gage was too high for the ancient marks, but that, on account of the current state of the water, this could not be fully ascertained, unless an accurate level were taken; and this you desired me to ascertain by taking a level accordingly.

I then observed to you, on considering the situation of the two flat stones, which seemed ancient marks, that they, probably, would be found not to be upon a level, as they have been generally considered, and as they are supposed to be by the wording of the act of parliament, which refers them to the level of the same head of water flowing down the Manifold ditch, and if not those two stones or marks, (the water being directed to be kept level therewith), the one communicating with the head of water before it has passed the gage, and the other with the tail after it has passed it, will become *bonâ fide*, two separate standards, one to regulate the height of the water above the gage, and the other below it, that have been originally placed with this intent, viz. to regulate the quantity of water that will pass the gage with a given descent or declivity, as is pointed out to be necessary in my said report of the 3d of May, and to which I beg leave to refer; which matters, with what else might occur as material to the subject, in order to ascertain a just measure of water to be taken by the company, you desired me also to examine at the same time.

Accordingly, upon the 29th of May, I took a set of levels at this place, from which it appears—

1st. That

1st. That the roof of the stone tunnel composing the gage is full five-eighths of an inch higher than the top of the old part of the flat stone mark, at the Chalk Island, which marks the height of the water before it passes the gage.

2dly. That the top of the Tumbling bay, across the Manifold ditch, which serves as an over-fall to let the overplus water taken into the balance engine, and passing by the Manifold ditch, return into the river Lea, when it is too much in quantity to be taken in at the gage, is full half an inch higher than the top of the mark at the Chalk Island.

3dly. That the ancient flat stone or standard, near Chadwell spring, which communicates with the water of the New River after it has passed the gage, is near upon three-quarters of an inch lower than the flat stone at Chalk Island, that communicates with the water before it has passed the tunnel.

From the above levels it appears, that if the surface of the water be kept continually to agree with the two marks, one for the head water, the other for the tail, (the difference of level being three-quarters of an inch), that a constant equable quantity of water will continually flow from the Manifold ditch through the gage into the New River, according to the apparent intent of the act of parliament, because

2dly. That if the two ancient marks had been found upon a level, and the water's surface had been kept even with those marks, the water would remain stagnant in the trough or gage, and none would have run from the Manifold ditch to the New River.

3dly. That if the water be kept even with the two marks above referred to, then the gage will not be filled so as to vend a full bore by about five-eighths of an inch in height or depth.

4thly. That if the gage be made to vend a full bore of water, then the water must be kept full five-eighths of an inch deep upon the Chalk Island mark, and if the water be at the same time only even with the standard at Chadwell, there will then be a fall at the gage of $1\frac{1}{8}$ inch, which will be almost double to what it ought to be.

In expressing myself as above, I have referred my measures to the two ancient flat stones or marks; the one at Chalk Island, after the water has passed the brick arch from the Manifold ditch, the other near Chadwell spring; because these, it appear to me, are

the only marks remaining that have the appearance of having subsisted at the time of passing the act above mentioned; the gage itself, which at that time is recorded to be of wood, is now rebuilt with stone, and the constituent parts, viz. the tunnel, with white marble, which, in point of length, breadth, and height, agrees with the dimensions specified in the act.

The old flat stone near Chadwell spring appears to be entire, but one-half of the old flat stone at the Chalk Island seems to be gone, and to be replaced with one of a more modern date, which is at or near upon one-eighth of an inch higher than the old one.

Upon both the upper surfaces of the old flat stones there are grooves or channels, cut of about one-half an inch deep, round about near the border, with openings to the outside, the intent of which, as it would seem to me, has been, that when the water comes near the level of the surface of the stones, it will, by flowing into these channels the more readily shew when the surface of the water is in reality even with that of the stones; which is to me a convincing proof that the surfaces of these two ancient flat stones are in reality the capped stones placed as standards, and referred to in the act. I must further remark, that the new part of the flat stone of Chalk Island mark is not grooved like the old one, and that upon both this and Chadwell spring, flat stones are placed round, or octagonal stones, of about two inches in height, which form a step or rise of two inches, and the middle of the step is covered with a rounding cap or head, reaching some inches higher, both which steps and their caps, appear to be of workmanship much more modern than the flat grooved stones; but for what purpose there placed does not appear to me.

It is said above that the top of the Tumbling bay, across the Manifold ditch, is full half an inch higher than the standard mark of Chalk Island; that is, than the surface of the old part of the flat stone there, from which all my levels were taken, but it is to be understood that the top of the Tumbling bay, as here taken, is the top of an iron bar which forms its crown, over which the water falls; but were this iron bar removed, so that the water might run over the stone upon which it lies, then the top of the Tumbling bay there would not be higher, but rather lower than the Chalk Island standard mark. Whether this bar was placed upon the top of the stone-work in the original construction of this Tumbling bay, or has been placed there since, or upon what occasion, does not appear to me, but it would seem that the whole of it has been done new since the date of the act, as there is a date upon it, I think, of 1746.

Upon

Upon the whole matter it appears clearly to me, that if the New River Company take such a body of water as will run through the tunnel of their gage, without raising the surface above the level of the roof thereof; that is, without any pen, and provided an equal depth of water flow over the two capped stones or standards, at the two places above mentioned, so as to produce a declivity equal to the difference of elevation of the surfaces of the two said stones, they would not take more water than they would by the act have been entitled to, if their gage had corresponded with the two said standards: but if the New River Company take no more water than will flow through their tunnel or gage, when the surface of the water is kept even with the two capped stones or standards, then the difference will be in their disfavour, as they will then take less water than they would have been entitled to by the act; but yet, though the surface of the water above the gage were kept even with the Chalk Island mark or standard, if the surface of the water below the gage were kept below the Chadwell standard, the effect would be by increasing the declivity to draw more water through the gage than the due quantity: and the widening and deepening of the river below has a manifest tendency to produce this effect, as is fully stated in my said report of the 3d of May, therefore, though it now happily appears that there are distinct marks by which the quantity may be regulated, yet, by means of the improvements made, the whole being in the power of the company's servants, they are able to take a quantity far exceeding that specified in the act.

J. SMEATON.

Austhorpe, 18th July, 1781.

RIVER

RIVER URE WORKS.

The REPORT of JOHN SMEATON, engineer, upon a view of the works upon the river Ure, taken the 27th April, 1770.

AT the request of the committee of the Ure navigation, I proceeded this morning, attended by Mr. Myers, Mr. Pashley, and Mr. Moon, from Bondgate green to Milby lock, and observed as follows :

1st. The bason at Bondgate green seems to be set out properly enough, if any thing, too near the road ; it seems best to place the warehouse at the head, or upper end thereof, and to bring in the water of the Skeld, in a subterraneous tunnel, through the little enclosure on the south side of the house, near the south end of the chain bridge, placing a draw-gate at the head to shut out the floods, and regulate the water, with a proper grate before it : the surface of the Skeld, as it may not be high enough to answer the level of the head canal, as now set out, and in part completed, may be raised by forming an artificial shoal or dam, a little below the flood-gate, with rubble, whose interstices being wrecked full of sand and gravel, may easily be made to pen the water to the height required, and be very durable. In some convenient part of the head canal, if beyond the high ground, the better, it will be proper to place an over-fall, of at least twenty feet in length in the crown, and high enough to pen a mill's water over the artificial shoal above mentioned, before it runs over the over-fall, in order that in dry seasons the water of the river may not run waste down the canal, after the works are filled to a sufficient height.

2dly. All the banks about Bondgate green to be made at least one and a half, but better if two feet above the ordinary navigation's surface, supposed to make four feet depth of water, and to be at least nine feet broad at top ; and in case this is not higher than the rise of the floods of the Skeld, to be increased in height till the floods will be prevented from making their way into the canal.

3dly. I staked out the remaining part of the canal from Bondgate green to Rhode's field lock, and set out the place for Rhode's field lock, and advise that the batter of the sides of the canal that remain to be done, be made five feet back on each side, for every three feet perpendicular.

4thly.

4thly. The rise, according to Mr. Jessop's levels, from the upper gate thresholds of the Oxclose lock to the surface of the water in the head level, as now set out, is twenty-five feet; but as it was proposed to raise the water in the reach above Oxclose lock, one foot extra, that is, to five feet above the upper threshold of the said lock, there will then remain twenty feet for the difference between the surface of the water in the reach over Oxclose lock, and the surface of the water in the head level, to be divided into two locks' rises; but being informed by Messrs. Myers, Pashley, and Moon, that the bottom of the cut, as it now stands, finished below Bell Furrows locks, is yet two feet higher than the upper gate threshold of Oxclose, it will follow, that either this cut must be deepened from Bell Furrows lock tail, for a considerable length downwards, that is, in all the deep part of it, or the water must be raised two feet extra, that is, to six feet upon the threshold of Oxclose lock; and observing upon view, that the sides stand very steep in the deep cut, and the bottom narrow; observing also, that Oxclose lock, is built sufficiently high and strong to bear an additional extra rise of two feet, I look upon it as far more eligible to do this, than to deepen the cut. In this case, the banks of the cuts in the low grounds next Oxclose lock will require to be heightened and strengthened, and the waste holes in the upper gates to be stopped, and in lieu thereof, to place a side wash or over-fall, near above the lock, for discharging the waste water into the river, the crown to lie about two inches above the gage height of the canal's water, that is, six feet two inches above the threshold, to be twenty feet length in the crown, but the stone setting may be contracted to ten feet at the tail: this being the case, there will remain nineteen feet difference between the upper and lower reaches of the canal, to be divided into two equal rises of nine feet and a half each, in consequence, the piquet at Bell Furrows lock, set by Mr. Jessop, being fifteen feet nine inches above the upper gate threshold of Oxclose, it will be thirteen feet nine inches above the lower gate threshold of Bell Furrows, four feet three inches above the upper gate threshold of Bell Furrows, and the same above the lower gate threshold of Rhode's field, that is, three inches above the surface of the water in the reach between these two locks; then raising the upper gate threshold nine feet six inches above the lower at Rhode's field lock, the same as at Bell Furrows, the whole will answer to make four feet water in the respective reaches. It will be proper to have an over-fall also at Bell Furrows lock of twenty feet long, placed about three inches above gage height; these over-falls have been found absolutely necessary, even where the waste holes have been applied, to prevent damages by overflow of banks, when the cloughs of the lock next above are left running, either by carelessness, or with a design to do mischief, the waste holes not being sufficient to discharge the full bores of water from the cloughs. N. B. As the bottom of the canal below Bell Furrows lock may not be quite two feet
above

above the upper threshold of Oxclose, it will be proper to place the lower threshold of Bell Furrows lock, at least as low as the bottom of the canal below it, and if any difference, to divide the two locks accordingly, which, if not perfectly equal, is not material.

5thly. It seems as if some dredging would be necessary below the tail of Oxclose lock; but of this I could not well judge, on account of a fresh in the river.

6thly. The dam at Westwick Wath, being undertaken to be completed by contract, it is sufficient to say, that I desired the undertaker, upon the place, as to the completing of his scheme, the cut being very deep, and the sides steep, it seems at present a good deal filled up, and I fear, being loose sandy matter, will continue to be troublesome, even after it is cleared.

7thly. The shoals lying below Westwick Wath, from the fresh in the river, had so much water upon them, it was not possible for me to judge, whether the clearing of them, or building a small intermediate lock and dam, as originally proposed, will be preferable; nor can I properly judge of this matter, but when the river is in its weakest state of currency, when it will be right to sound it with a boat. It is certain, that if the shoals can be effectually cleared, it will be preferable to a lock and dam, even if attended with a greater expense, but this I rather doubt, for in my original scheme, which was only for three feet certain water, I proposed four feet where the water was liable to be drawn down by the mills, and, therefore, supposing Boroughbridge dam to pen only one foot dead water over the shoals below Westwick, on raising it by a dam two feet higher, there would be three feet certain water; whereas, to deepen those shoals two feet, would in effect, make but two feet water, when reduced one foot by the mills; the shoals must, therefore, be deepened three feet, to do the same thing by deepening as by raising the water two feet, and by like reasoning, to secure four feet certain water, there ought to be five feet at a dead level within the pen of the mills; now, if this happens to be more than the general depth of the river between shoal and shoal, the whole will be to be deepened from whence the shoals begin upwards; and if this be the case, which can only be determined with certainty by sounding at a proper season (which I never had an opportunity of doing), the expense may very far exceed that of a lock and dam.

8thly. Respecting the lock and tail cut at Milby, two things offered for consideration; first, a double rend in the wall, near the N. E. angle of the return of the tail wing, one
being

being in the face of the wall next the lock's passage, the other in the flank or return of the wing. They both appear to be occasioned by a set in the foundation, probably owing to an over-weight, in extending the masonry of the wing beyond the ground timber; at the same time, as I understand that the ground timber was not supported by any piles underneath, nor had any plank piling on the down-stream side to keep the matter under it, and but very inconsiderable plank piling on the up-stream side; his, considering that the natural bottom as is said, was very weak and springy, renders it more to be wondered, that no greater derangements have happened. At present it has the appearance of having done settling; and if so, the best thing that can be done, will be to double cramp the capping, and to cramp every other course downwards, and then running the joints full of fine terras mortar made liquid, doing about fifteen inches at a time, and then waiting till what preceded has set: but, in case any thing further appears, to drive down close to the face of the ground timber a sheet of rebated plank piling of four inches thick, which may be driven down to the level of the floor by a set, and lastly, when by the action of the cloughs, the matter appears to be driven away from below the timber, to support the whole by dropping in a quantity of rubble to fill the same within six inches of the level of the floor, and to extend as far as the ground shall appear to be taken away, or five yards below the apron.

The other affair respecting this lock's tail is the shooting in of the land bank on the north side, which being a tender springy soil, especially as is said towards the bottom, has been in all probability occasioned by its being dug over steep, and too great a weight laid upon the top, by the matter which came out: there seems to me at present no effectual remedy for this, but to wheel the extra matter so much further back, that a slope may be formed of at least two to one from the level of the water's surface, upwards, and beginning the foot of the slope where the ground is whole; allowing also a set-off for the road, at or about the natural surface of the ground, then clearing away the piles and timber as much as possible, when the water is low, by dredging, or otherwise to deepen the channel, letting the loose matter come in, and gradually forming its own slope; and if, after this, a layer of rubble of about a foot thick be deposited upon the face of this underwater slope, beginning at the bottom, and diminishing the thickness upwards, in all probability the weight of this rubble will so consolidate the ground, as to prevent its sliding in future.

J. SMEATON.

Austhorpe, 12th May, 1770.

The

The REPORT of JOHN SMEATON, engineer, concerning the repair of the navigation dam at Westwick Wath, upon the river Ure.

HAVING carefully computed the probable expense of building a new dam at Westwick Wath, including all materials; and also the probable expense of making up the breach, and repairing the dam as it now stands, in order to render the same effectual, I find the difference will scarcely amount to £200, and as the old materials, I think, must be of that value in the new erection, it seems there will be no material difference in point of expense: however, as the making up and repair of the present dam may be the sooner executed, and consequently a saving of time in the opening of the navigation, and though the present dam so repaired will not subsist upon principles so regular and uniform as the proposed new one, yet, as the new dam I have computed upon is but 160 feet between the land walls, and the old dam, when made up and repaired, will be above 200. I am of opinion, upon the whole, that the repaired dam will be as safe as the new one; I am, therefore, inclined to advise the commissioners to the repair of the dam as it now stands.

The general method in which I propose to do it, is to let the timber frames stand as they now do, as a pen to the water, and to add a slope of stone on the down-stream side, extending twenty-four feet in base, and after that (that is, below the skirt) to lay in a body of rubble to the breadth of twenty-four feet more, by way of rough apron or security to the skirt. While this is doing, the breach is gradually to be filled with a body of rubble, and the top of it at last to be raised fifteen or eighteen inches higher than the crown of the dam; by this means, whenever more water than that thickness goes over the dam, it will begin to find a vent over the rubble dam likewise. When the rubble dam is made up, it will be made water-tight by throwing in upon the slope side up-stream several boat loads of gravel, which will shut up the interstices of the rubble, and a few boat loads of earth upon that will render it quite water-tight.

ESTIMATE of the quantity and sort of materials to be used in making up the dam and breach at Westwick Wath.

	£	s.	d.
The slope surface of the dam, being twenty-four feet broad, twenty inches in depth, and 100 feet wide, mean length will contain 4,600 cube feet of scapelled stone, which, if brought from the quarries near Ripon, and put in place at seven-pence, will be	-	116	13 4
			To

	£	s.	d.
Brought over	116	13	4
To rubble for filling under the settlers, and covering the earth apron above the dam, 327 cube yards, which, if produced, and laid in place from the before mentioned quarries, at two shillings, will come to	32	14	0
To one cube yard of earth per foot running, in order to form an apron above the dam, this getting, and properly depositing, at sixpence for 100 feet,	2	10	0
To rubble in the skirt apron, supposed at a medium twenty-four feet broad, and three feet thick, will, in 120 feet length, contain 320 yards, which, at two shillings, will come to	32	0	0
To 100 yards of rubble to line the shore on the north side along the apron, &c.	10	0	0
To 120 feet running of bearing piles, stringed-piece and grooved sheeting, of three inches thick, and seven feet long, at thirteen shillings per foot running,	78	0	0
To facing up the south side of the south wall of the cloughs, and putting it into the form as directed,	15	0	0
	286	17	4
To contingencies on the above, at ten per cent.	28	13	0
	315	10	4
To making good the body of the present dam,	330	0	0
To 3,300 yards of rubble for making up the breach, at two shillings,	12	0	0
To six boat loads of gravel and earth, at forty shillings each,	34	4	0
Contingencies at ten per cent.	376	4	0
To making up the breach,	691	14	4
Total,			

It is to be observed, that though the prices are added to the above in order to fill up the blanks, yet the quantities are the only circumstances which can properly be ascertained by me, as a thorough knowledge of the prices of materials and carriage, upon which the sum total greatly depends, can only be had from an acquaintance with the country, and which, I apprehend, many of the commissioners to possess to a much greater extent than myself.

In regard to the rubble skirt or apron, it cannot be completed till after some considerable freshes have happened, that the holes made thereby may afterwards be filled up with a proper body of rubble, which will probably be required to secure it, and which ought to be got down in readiness, that after the floods have happened, it may be applied before any damage is done by the want of it.

If opportunity serves, the breach may be begun to be filled up, as soon as the materials can be got to the place, but not so high as to pen the water over the dam, keeping always the body of the rubble highest and strongest next the land, to prevent its widening.

The quantity contained in the above estimate supposes the breach such as it was when I saw it, viz. about thirty yards wide, and eight feet deep, at ordinary water; proper allowance must therefore be made for such alteration as has happened, or may happen, before it is put into a defensible state.

The first work for the body of the dam is to complete the piling of the skirt, and at the same time, filling in the rubble for the body, over which the floods will go without damage. The skirt of the dam is supposed to be above water in a dry season, if it should not so happen, after the water has been let off as much as can be, the skirt must be raised, while the underside of the string-piece is about level with the surface of the tail-water.

J. SMEATON.

Austhorpe, 19th January, 1771.

N. B. If the rubble cannot be put in place for 2s. 6d. per yard, or under, I believe it will be adviseable to begin a new dam in a new place.

VIEW of the works of the navigation of the river Ure, on Tuesday, May 14th, 1771, by JOHN SMEATON.

MILBY LOCK AND CUTT.

THE tail of Milby lock, the wharfing on the south side wants lining with rubble inside the timber work.

The down-stream angle of the stone work of the lock on the south side is cracked in the same manner as the north side did the last year, when settled, it may be cramped and grouted (that is, filled with liquid mortar), as the former has been done.

The current over the top of the lock having taken out some of the earth behind, the walls near the upper gate turning posts should be filled with rubble, and lagged at the top to prevent its blowing out.

A breach in the south bank near the lock should be made up and stout, and some low places where the water has run over should be raised.

A sand is said to be gathered in the cut above the bridge, and the head of the cut has a narrow bar of the original bank of the river, that has never been taken out, over which there is but three feet water at dam's height; if an opportunity offers of drawing down the river, both the above will be easily cleared by setting men into the water, but if not, the head may be cleared by a large rake, which will be useful on future occasions in clearing heads and tails of cuts, and the sand within the cut, whenever it proves obnoxious to the passage of vessels, may be taken out, by drawing a sheet of rebated piles across the cut above the same, to be well supported down-stream by stays, and then drawing off the cut's water below by the lock's cloughs.

SHOALS IN THE REACH BETWEEN MILBY AND WESTWICK CUTS.

As the clearing of these shoals has been agreed for at the meeting on this day to a stipulated width and depth, they need no further remark.

WESTWICK CUT AND DAM.

The tail of the cut being fanded up, and there being a deep part of the river below,
it

it is presumed the sand may be blown out by the action of the lock's cloughs, if not, it must be cleared with the rake. The wharfing at the lock's tail, it seems, will want supporting with rubble like Milby.

The cut above the lock has a breach into the river which will want to be carefully made up of a good height and strength, and the matter well consolidated, and some other places on the side next the river will want raising and strengthening where the water has run over.

The whole cut wants clearing, and the sides made more sloping; the bridge wants finishing.

The breach at the dam, though grown, it is said, about six yards wider than when I first viewed it, yet, by being less deep, I do not apprehend to be in a materially worse condition than before: this being contracted for upon particular plans and sections, which have been amply explained to the undertaker, needs no further mention here.

THE LONG CUT, &c.

The ford at Oxclose, not having been completed over the river, the part unmade is blown to a considerable depth, and unless repaired before any heavy freshes come on, what is done will require to be removed, and the whole begun in another place.

The banks at the tail of Oxclose cut will require to be guarded with rubble as the former.

The over-fall at the head of this lock will require to be constructed as per former report, to convey the waste water: it may be done in a sloping form, with scapelled rubble setting, and the tail of the trench to convey off the water to be well guarded with rubble on entering the river or tail cut.

The terminations of the parapets of the bridges should have a heavy stone laid on each, otherwise the bricks cannot be properly supported, and will follow one another.

The banks for thirty feet at the tail of Bell Furrows lock should be wharfed up with rubble walls, inclining about one foot in four; they may be built without mortar, but should be covered about one foot above the cut's water, with pretty heavy stones, a little scapelled by way of capping.

The

The tail of the drain that brings down the water from the over-fall should be conducted through the bank, and the bottom well set and secured at the termination by rubble.

The head cloughs of this lock want some amendment, and the shutting of the lower gates against the thresholds should be re-examined when the water is off.

Rhode's lock should be wharfed at the tail in the same manner as mentioned for Bell Furrows, and the north clough at the head wants rectifying.

The leakages that appear in various places near those locks are nothing more than what always happen in gravelly soils. The water is to be conducted in small gutters from lodging upon the surface of the lands for the present season, and before the next, they will probably disappear. If, upon drawing off the water, any suspicious places appear, they will be best stopped by being puddled with corn mould earth.

The bank near the sunken tunnel on the south side wants considerably to be strengthened, and the mouth of the tunnel to be finished: it should be made wider at the entrance, and an upright bar or two be put down to prevent hay or bushes that may enter from choaking it; some small part of the bank on the north side near the elbow next the turnpike road should be somewhat strengthened.

I apprehend it will be necessary in some convenient place in the upper reach of the cut to have a rough over-fall, something like that proposed at Oxclose; for, if the clough by which the water enters from the Skeld, should happen in a flood or spout to be left running, the banks of the cut will infallibly overflow, and probably make a breach before it is discovered, especially, if happening in the night; this over-fall may be made on the south side, near the said tunnel, and its water be conveyed away through the same.

J. SMEATON.

Austhorpe, 29th May, 1771.

The REPORT of JOHN SMEATON, engineer, upon the state of the navigation
of the river Ure from Ripon to Boroughbridge lock.

HAVING carefully viewed and founded the river and cuts the 28th September last, I find that when the cuts are cleaned, there will be four feet water from Ripon in to Westwick lock.

From Westwick lock downwards, which is now the subject of the principal impediments, I find that in the state the river then was, viz. four inches water over Boroughbridge dam, there was no more than three feet nine inches and a half water over the threshold of the lower gates of Westwick lock, so that when the water is reduced to dam's height, and subsided nearly to a level, as in time of droughts must always be the case, this, together with the soundings taken by Mr. Jessop last summer, convinces me, that in that state of the river, there will not be more than three feet water over that threshold. I found likewise that the places that had been dredged, had, at the time of my view, four, and four and a half feet water; but that in several places between and below the places that had been dredged, the river's bottom was no more than three feet and a half, and in one place, viz. at Rockliff shoal (where I originally proposed building the intermediate dam) there was only three feet three inches, all below to the cut's mouth at Boroughbridge being at least five feet, and in general six feet and upwards of water: hence it appears, as also from Mr. Jessop's soundings taken at the time before mentioned, that in a dry season there will not be more than two feet six inches on Rockliff shoal, with a full dam at Boroughbridge, while at all other places, there will be about three feet.

From the cut's mouth to Milby lock there are some impediments, but as it is always in the power of navigators to remove those, and there being four feet water over the upper threshold at Milby, at dam's height, I consider this cut as capable of complete four feet water with a full dam.

It seems, therefore, that in case a three feet navigation in dry seasons, three and a half feet in common ones, and four feet in open winter weather, will suffice, that this may be procured with a full dam at Boroughbridge by lowering Rockliff shoal six, eight, or nine inches; but then, in case the miller of Boroughbridge mills should draw his water within head (as in dry times he can very easily do) the navigation, as it now stands, must,

must, at those times, be considerably defective, and as the original expedient of building a dam at Rockliff, or any other intermediate dam may not be perfectly agreeable to the miller at Boroughbridge, he may possibly see it to be (as it most certainly is) for his interest to enter into a firm agreement with the navigators not to draw his water within dam, and to prevent its running over and wasting in dry seasons, to fix on a sett of boards of nine or ten inches broad, which I can engage so to make, that they may be struck and removed at any time of flood, and if those are kept in repair at the joint expense of the navigation and mill, it will be a real improvement to the mill as well as benefit to the navigation, by giving them so much additional head of water when they most want it, and the mill will then have as good a latitude in drawing as it now has.

If the above cannot be acceded to, then it appears necessary either to lay a catch dam across the river just below the head of Boroughbridge cut, or to build a lock and dam at Rockliff shoal as first intended.

The former expedient will cure the present inconveniences in the most effectual manner, because it will render the navigation entirely independent of the mills; but at the same time, I cannot take upon me to report, that in case the catch dam is raised as high as the mill dam (which, as the works are now laid, is absolutely necessary) there will not be a real injury to the mill; on the contrary, my opinion is, that there will be a real injury, which will require recompense, and if this recompense could be easily agreed upon it would be well, but otherwise, as it is of such a nature as not readily to be adjusted by a jury, it appears to me better to submit to some extra charge and inconvenience than embark in a troublesome piece of litigation.

The dam at Rockliff shoal, as originally proposed, was intended to raise the water two feet, in order to clear all the shoals above without dredging; but, as now they are in a great degree cleared, it will be sufficient to raise the water there a single foot and this may be done by a rubble dam; that is to say, by adding to the present, and making an artificial shoal, so as to keep up the water a foot above its present surface, that is, much about as high as the shoals intermediate, between this and Westwick, penned the water before they were cleared away. By the side of the shoal to be made at Rockliff, there must be a lock to give passage to vessels, but as this lock need not to be raised higher than till the vessels can go over the shoal itself, I apprehend the whole of this business at Rockliff may be done for about £1200, which may be more particularly estimated if this mode of relief be adopted.

When

When this is done, and the Boroughbridge cut cleared so as to be six inches below the upper threshold of Milby lock, together with the cut above also cleared, and particularly the tail cut of Oxclose lock, there will be then complete four feet water, with fill ponds in the driest seasons: and after the mill at Boroughbridge has drawn down one foot, there will still remain three feet in the Boroughbridge cut, and should the miller then attempt to draw and keep down his water below one foot within dam, as this cannot be with any other view than to distress the navigation, I would then advise to lie in a shoal at the head of Boroughbridge cut, which will give him the command of the pond to one foot within head, but will prevent his wantonly drawing it lower.

I would advise that the navigation should be furnished with proper dredging utensils for making such clearances as can be done without taking off the water, the principal of which is a machine of known construction, used in the neighbouring river, called a hell rake: also a sett of grooved piles, with proper beams and braces, for readily taking off the water from any cut, so as occasionally to clear it by hand.

For want of the former, the head of Boroughbridge cut has never been sufficiently cleared, and for want of the latter, the silt that has been lodged there in time of floods is obliged to remain: but I am apprehensive, from the position of this cut's head, it will be so liable to gather silt, that it will be worth while to have a staunch fixed at the head; by shutting of which the water may be readily taken off the cut, and the soil, while light, washed out by a current of water.

J. SMEATON.

Austhorpe, 9th January, 1772.

P. S. In my report of May 12th, 1770, I advised that the three overfalls from the ponds of Oxclose, Bell Furrows, and Rhode's field locks, should be made twenty feet in the crown; now the two already constructed above Oxclose and Bell Furrow, are not above half that dimension; and though they may answer the purpose in ordinary, yet I shall not be surpris'd if on extraordinary occasions, damages are done for want of a proper vent for the water, as well as from the pond from Rhode's field lock to Bondgate green, for want of one being constructed on this line; somewhat near the tunnel I apprehend will be the proper place.

J. S.

HEWICK

HEWICK BRIDGE.

To his majesty's justices of the peace assembled in quarter sessions at Knaresborough in the West Riding of the county of York.

The report of JOHN SMEATON and JOHN GOTT, engineers.

See plate 5, fig. 5, page 142.

GENTLEMEN,

HAVING carefully viewed Hewick bridge, and the state of the river there, and having considered the several points referred to our opinion by your order of Skipton sessions for the West Riding of Yorkshire, of the 23d of July last, we beg leave to report upon the points referred to us, which are as follows:

1st. Whether any, and what damage has been done to a field adjoining to Hewick bridge, belonging to the right honourable lord Grantley, by the current of the water?

2dly. How the same may be prevented?

3dly. From what cause the water takes its course, so as to press upon, and wash away the said field.

To the first we answer, that it appears to us that considerable damage has been done to the field next below the bridge, on the west side of the river; and that from the very loose texture of the ground of this field, being a very deep rich soil, it is likely that still greater damages will ensue, unless timely prevented by an adequate remedy; but, in order to point out the remedy with greater propriety, it will be necessary to give our opinion previously upon the last point referred to us, viz.

3dly. From what causes the water takes its course, so as to press upon, and wash away the said field?

Nothing is more common than for rapid rivers, taking their course through grounds composed of fine deep soil, such as that under consideration, to make depredations

upon them so as to change their course, of which very striking instances are to be seen in the meadows below this and Westwick Wath, and this kind of depredation often originates from slight, and even from unperceived causes; they are not always manifested to common perception, for it often happens that a change made in one part of the river, will be the cause of depredations on another, and which, when begun, have generally a tendency to grow worse, and not to cure themselves, or to stop, till some powerful remedy is applied.

The forming of the new arches at the two ends of Hewick bridge does not appear to us to have any direct tendency to produce the bad effect complained of; because the wear or wharfing annexed to the south-west land stool wall, as originally made, extending to or about sixty feet in a direct line, appears to us to stand in a proper direction to carry the stream of the river away from the part of the land in question, rather than towards it, or so as to make it bear harder upon it than before, and the arch at the opposite end is too remote to have any material effect as to this land; we find ourselves therefore compelled to seek for the cause of the disaster from some other source.

According to information given us, there was, formerly, a deep pool below the bridge, and at some distance a bed of gravel appeared in the low state of the river; at present the pool is nearly filled up, and the gravel bed much increased in size and breadth; which having a natural tendency to divide the current of the river, will cause it, in consequence, to press hardest upon the lowest and weakest side, which is the very spot in question.

To this accession of gravel below the bridge we attribute the circumstance of the water taking its course so as to press harder upon, and wash away the said field, in a greater degree than formerly; but from what cause the gravel is deposited here, in a greater degree than it used to do, is a further question. It cannot be from the broken ground, because the water's current is in succession from the gravel towards the broken ground, and not from the broken ground towards the gravel bed, and the ground altered in opening the arches, at and above the bridge, is far too inconsiderable to produce the quantity; besides, the fine soil there is deep, and does not appear to produce gravel in great proportion.

We are therefore obliged to notice that about a quarter of a mile above the bridge, a work has been made by which the whole channel and current of the river has been diverted,

diverted, and now passes altogether through a new cut, which, in gravelly soil, and being worn considerably wider than it was originally made, large quantities of gravel have doubtless been gradually brought down the river therefrom, since its first opening in the year 1779, and still larger quantities appear to be travelling therefrom, capable of increasing the evil we have pointed out.

It is to be observed, that this cut being a work prior to the alteration of Hewick bridge, it would require a time for the gravel first loosened from the new bank and bottom of the cut to travel progressively on the bed of the river down to Hewick bridge, and it would be some time before the gravel brought down and lodged in the deep pool, below the bridge, would become perceivable. We find ourselves, therefore, obliged to consider the depredation of the river upon the ground in question, in a greater degree than formerly, and the alteration of Hewick bridge, as contemporary events, and not that the latter was the cause of the former, but that the primary cause thereof was the making the new cut, and forcing the main current of the river to pass through it by a dam made for that purpose.

Lastly, we shall now consider the second point, viz. how the ill effects of the water's pressing harder upon the said field may be prevented?

Now it is to be observed, that by way of prevention, an addition has been made to the end of the weir before mentioned in the way of a jetty, intended by contraction to remove the gravel bed, and work a channel through it, and thereby to save and ease the weak side, which is the west; but by continuing it in the same line further out by 120 feet than the original weir, that direction has carried it too much towards the opposite side, so as too much to straiten the river in that place, which, in of time great freshes, gives it a tendency to spread when it quits the jetty, and finding the greatest declivity towards the broken ground, the set of a considerable part of the current is almost directly turned upon it, and as the rapidity of this part of the current has made itself a deep channel beyond the end of the jetty, this tends still to increase its action and pressure upon the said field.

Had Mr. Smeaton been called in before the jetty had been run out from the weir, he should have advised to have fortified the curve of the broken ground by lining it with a slope of rubble stones promiscuously thrown in, and not to have attempted to regain the ground by a jetty. As it is, it may be a matter of consideration depending upon the estimates herewith delivered, whether to carry forward the jetty 420 feet further
in

in the direction shewn in the plan, (in which direction about four yards of its extreme end is already turned) or to remove the jetty, and dispose of its materials, so as to form a slope against the broken border, as far as they will go, completing the remainder with fresh materials, as either method we look upon as a likely, and the most practicable way to preserve the ground in question from further depredations.

References to the plan, plate 5, fig. 5, page 142.

THE black line marked B B B, shews the state of the ground before the bridge was widened.

A A, the jetty, 159 feet long.

The quantity of land washed away on the south-west side of the bridge, since it was enlarged, is one rood thirty-five perches, and it is probable, if something be not done to prevent it, that in time the water may take the greatest part of the field away.

ESTIMATE for lining the broken bank near Hewick bridge with a slope of rubble stones, according to the method suggested by Mr. SMEATON, in which case the ground will not be gained.

	£	s.	d.
The length being at present 550 feet, to form a sufficient slope, will contain at an average, three cube yards of rubble to a yard running, that is, it will contain 550 cube yards of stone, which, at 3s. per yard, will amount to	-	-	-
Allow for deposition and contingencies	-	-	-
	82	10	0
	7	10	0
	90	0	0

The estimate to continue the weir from A in the plan to B, being in length 420 feet, will cost 130 0 0. By this latter method there is a possibility the ground may be regained.

J. SMEATON.
JOHN GOTT.

Leeds, 1st October, 1782.

BIRMINGHAM

BIRMINGHAM CANAL.

QUERIES by Mr. COLEMORE, with Mr. SMEATON's answers, concerning the Birmingham canal.

QUERY 1st.—To see if the present leakage is not to be remedied, and that at a moderate expense?

Answer.—The present leakage is no ways alarming, and nothing more than what might be expected from the nature of the soil through which the canal passes for about three-quarters of a mile preceding the present termination, when particular care is not taken to prevent it. The soil is a red sand, tolerably firm, while it lies in its own natural bed, and underneath is a red sandy rock, close enough in the lump, but with open joints that frequently occur. This kind of soil is commonly, in some degree, leaky at first, and more or less so, and for a greater or less length of time, according as proper remedies have been at first applied, and in proportion as the water introduced into the canal has more or less of the requisite quality to keep it tight. This kind of soil, however, though leaky at first, in time grows tight of itself; insomuch, that it would require a greater degree of art to prevent its growing tight, were the percolation of the water through the pores of the sand for a length of time a requisite quality. I am of opinion, from what I have seen, that the most effectual methods have not been taken at first; and I am further of opinion, that had a proper use been made of the muddy water washed down from the marley and clayey grounds, &c. that do or might be made to fall into the canal in rainy seasons, by being carried in proper quantities through the course of the same, and discharged at or near the termination by means of a sluice, waste, over-fall, or discharger, so as to keep up a constant movement at times, when water is abundant: I say, had this been done when the canal was opened, and at all convenient times since, instead of its being discharged by an over-fall or waste, not far from the summit, and thereby the water towards the said termination rendered in a great measure stagnant, I am of opinion that the canal would have, by this time, been rendered so far tight as to have been without complaint.

Query 2d.—Whether it is, in its present state, considerable enough to endanger the navigation?

Answer.

Answer.—I do not, in the present state of the leakage, think it considerable enough to endanger the navigation, or even to be a great impediment to it, as it appears to me that the leakage will be much more than balanced by the lockage water alone, which must be discharged from this lowest stretch of the canal, by a waste or discharger if not by leakage; and if to this leakage we add the constant leakage of water through the locks, and the regulating water, which last Mr. Brindley has on another occasion said may be ultimately equal to the lockage itself; I say, all these things considered, it does not appear in any degree probable, that the navigation would be endangered, even supposing, what I can by no means admit, that it were always to continue as it is.

Query 3d.—To examine what probability can be assigned of the same inconvenience attending the extension of the canal to New Hall Ring, and if the suspicion of such inconvenience be a fair and sufficient reason for the company to alledge in bar of their being compelled to fulfil their agreement to bring the canal there?

To ascertain this, Mr. Colemore submits it to Mr. Smeaton to have the ground bored, as Mr. C. wishes to have his claim supported upon the clearest evidence, or to abandon it if he may be called upon so to do, upon any principle of equity and fair dealing.

Answer.—Not only from the general appearances, but from pits which I caused to be dug in Mr. Colemore's ground, in or near the course of the proposed canal to New Hall Ring, in order to lay the strata open to view; it appears to me that the ground from the present termination eastward, to New Hall Ring, is not less fit, and much of the same nature as that already passed through for about three-quarters of a mile preceding, and therefore must be subject to the like leakage, in proportion to its length, (which is under one-quarter of a mile), supposing it to be executed in the same manner: but as I am very well satisfied, that the extension may be made in such a manner as to be subject to much less leakage at first, and to be more speedily stopped, I cannot look upon the apprehensions of increasing the leakage, as sufficiently grounded to be a bar to the extension, especially when I consider the necessary supplies above mentioned, as a sufficient counter-balance, supposing the part to be made subject to a proportional leakage to that which is already made.

Query 4th.—To examine whether the termination of the canal, at New Hall Ring, be not equally convenient for the public with any other?

Answer.

Answer.—This is not properly a question for an engineer to answer, who cannot be supposed to enter into the particular conveniencies attending the commerce of a large trading town in a few days; but from what I have observed of the situation, and have seen of the town, I see no reason it should not be as convenient as any other that has been pointed out to me: but I am of opinion that the greater the number of the owners of wharfs, the better it will be for that part of the trading public, who are not immediately interested in the navigation.

Query 5th.—To estimate the expense of finishing the canal from its present termination to New Hall Ring?

Answer.—According to my estimate, the canal may be finished from its present termination to New Hall Ring, being 401 yards, according to the measure of Mr. Yeoman, for the sum of £473. 10s. exclusive of the value of two acres of land, which, at twenty-five yards broad, it will occupy, and exclusive of the particular charges that may attend the construction of the wharfs thereupon.

Query 6th.—To see if the shortest, the most expeditious, and the cheapest way the company can go from the present termination to their own ground, at the brick-kiln-piece, be not through Mr. Colemore's land, which lies on the east side of the Dudley road?

Answer.—This, I think, can hardly admit of a doubt; for, according to Mr. Yeoman's measures and the plan conjointly, the present termination of the canal is nearer to the specific point in the brick-kiln-piece, by way of Mr. Colemore's land, than by the other tract marked through Mr. Farmer's land, by a difference of 292 yards, and the length of tunneling will be less than half as much. The practicability of doing it either way, I think, is not to be doubted, but which may prove easiest length for length, I apprehend, cannot be certainly known but by executing them both: since, therefore, the chance of unforeseen difficulties is equal in the same length either way, the shortest runs the least risk of meeting them; and, upon equality of ground, the expense and time will be less in proportion to the distance. A shorter line may, indeed, be drawn from the present termination to the brick-kiln-piece, through the gardens and grounds of Mr. Baskerville, without touching Mr. Colemore's, but, I apprehend, this will not be found eligible on account of damages; and, upon the supposition that the company are to carry the canal to New Hall Ring, then the distance through

through Mr. Colemore's land, will be as near as any that can be drawn through Mr. Baskerville's.

Query 7th.—Whether it is not probable the company would at present prefer this direction, if they had it not in view to prevent Mr. Colemore from making any advantage by wharfs and warehouses, and to engross them wholly themselves?

Answer.—What may be the reasons why the company would avoid coming into any part of Mr. Colemore's grounds, is not easy for me to say with certainty; but so far as I am enabled to judge of the matter, it carries that appearance, and so I must imagine, till the company are pleased to explain themselves otherways in a manner more satisfactory. It may, indeed, be alledged, that though this passage to the brick-kiln-piece is nearer, and can be done at less expense than by the other line, yet, when done, that the distance from the point of departure common to both is less by the latter than through Mr. Colemore's: and, according to Mr. Yeoman's measure, the difference will be 114 yards, reckoning both ways from the said point; but then there will be double the length of tunnel, viz. about six chains through Mr. Colemore's, and at least twelve the other way, and I look upon a tunnel to be so great an impediment to the passage of vessels, when they are going in contrary directions, especially near wharfs, where they are often crowded, that the hindrance and loss of time will, upon an average, amount to far more by the increase of length of tunnel, than can be saved by a difference of distance of 114 yards: an under-ground tunnel is in some places an useful expedient, by substituting a less evil for a greater; yet it is still an evil always to be avoided, where it can.

Query 8th.—To consider if the canal be continued to New Hall Ring, whether the ground on the lower side of it would be hurt for building by the leakage?

Answer.—I am well satisfied the extension of the canal may be performed in such a manner, that there will be no leakage hurtful for building, as what may happen may easily be carried off in proper drains.

Query 9th.—To estimate the expense of making a brick side drain to carry off such leakage?

Answer.—I apprehend this is impossible to be done, because, on the supposition of leakage, it will be proper to make the drains according as the leakage happens to break out, and I do not apprehend the places can be assigned beforehand.

Query

Query 10th.—To consider if any risk to the whole navigation can be incurred by extending the canal from its present termination to New Hall Ring, and whether any, or what security, need be given the company against such risk, if Mr. Colemore were to continue the canal on his own account?

Answer.—The extension appears to me to be attended with no difficulty, but what occurs in daily practice. I cannot admit of any risk to the whole navigation in the carrying the same into execution. I, therefore, do not see that any security can properly be expected. No human judgment is infallible, and should any thing of so extraordinary a nature happen, as absolutely to require it, the same justice of parliament which may oblige the company to extend the canal, will, on a similar application, enable the company to shut it up again: but if works were to have a negative upon them by the prospect of chances so remote as this, it would be impossible to do any thing in the way of artificial navigation.

To the committee of the Birmingham canal.

The REPORT of JOHN SMEATON, engineer, upon the several matters referred to his inspection and opinion by the said committee, at a meeting held at the navigation office, at Birmingham, the 9th and 10th of October, 1782.

HAVING, in consequence of your directions and instructions, viewed the general scope of ground occupied not only by your present canal and navigation works, but also such further extensions, additions, and improvements, as you have had in contemplation; being on this view attended by your own engineer and surveyor, Mr. Bull and Mr. Snape; after full consideration, I am now in condition to answer some of the most material questions that you have done me the honour to refer to my enquiry.

In acquitting myself of this business, I find myself enabled to do it by taking the main body of your enquiries together, rather than by making answers to each separately, for by this method I shall be able to weave into one piece the whole bulk of matter that you have laid before me.

Your leading enquiries are, whether the course of the present undertaking, or the intended extension from the Wednesbury branch to the coal mines, with the several collateral branches, can be improved?

Having carefully viewed the several lines of extension pointed out to me, as well that leading from the New Hall branch, in the environ of the town toward Deretend and Bordsley, as that from the Wednesbury branch toward the collieries; I find the whole very judiciously and carefully laid out, so as to conduct the navigation in the best manner towards the several points proposed; and the means pointed out of returning the water by a tunnel from this low level, into the branch of the Wolverhampton canal, that is extended to Oker Hill by means of an engine there, will be very effectual, and attended with beneficial effects upon the whole navigation, as I shall more particularly shew hereafter.

In going over the several lines of this business, it forcibly strikes me that the principal leading hinge upon which the whole, both primarily and ultimately, must turn, is the
procuring

procuring a sufficiency of water, not only for supplying the extensions you have proposed, but for upholding and subsisting the navigation as it now stands, and in respect whereof the several claims made upon you by the millers, for restitution of the water intercepted for the supply of the canal, appears to me a very serious business; for as the value of all mills and streams of water capable of turning mills, which can be employed in the very extensive manufactures of this country, are very great in themselves, and also necessary powers for the very existence of the manufacturers; it therefore is not very easy to make a compensation in money that will be adequate to the thing taken away; besides, as the water taken away from the first, or any given mills upon a stream successively, turns the succeeding, the whole string of mills in succession have their respective claims upon you, so that the making the due and adequate satisfaction to them all, in their proper and proportionable degree, would be in a manner endless.

This, in a great measure, appears from the memorial of the gentlemen concerned in the mills of Aston brook, delivered to you gentlemen of the committee of the Birmingham canal, and bearing date the 28th of March, 1782, the matter of which memorial, though desired by you to be considered by me in the light of a secondary business, yet naturally leads to matter that appears to me the primary; and more especially as I understand that a similar demand has been urged by the gentlemen concerned in those mills, whose waters fall into the river Tame from the west side of your summit; and which claims in proportion to their value, that is, distance from the seats of manufacture, are undoubtedly capable of being supported with equal justice and propriety.

It appears then to me, and is plainly so understood by the gentlemen who delivered the memorial above referred to, that you have no right to any water for navigation without recompense to the mills, but either such water as you can collect into your reservoirs in such rainy seasons, when the mill ponds are overflowing, and the mills fully supplied, or such water as is drawn out of the bowels of the earth from the mines, which had not previously made its appearance in springs upon the surface; and, upon this footing, the securing of an adequate supply of water at all seasons, becomes a matter of the first import, not only to the success of any extensions that may be thought proper, but for securing a continuance and permanency to the present lines of navigation.

I will, therefore, now endeavour to investigate and lay before you,

1st. The supplies of water that your present canal should take, according to calculation;

tion; 2dly. The quantities that were actually consumed during the dry months of the summer 1781, and from thence deduce the quantity of regulating water that was actually consumed, with other useful deductions, shewing how the necessary quantity of water, for the maintenance of the whole, is to be maintained and secured.

1st. The length of your present lines of canal, taken together, is $27\frac{1}{4}$ miles; this, at the mean breadth of thirty feet, gives a surface of 4,316,400 square feet. The soakage and evaporations in dry seasons, I have usually computed at the loss of one-fifth of an inch per day in depth, which, upon the whole surface as above, amounts to 71,940 cube feet: but as we have not so distinct an idea of high numbers, as those of a smaller denomination, it may be more commodious to reduce our measures to that of the ordinary measures of the canal locks; which, according to my computation, at six feet deep, contain 3,388 cube feet, which, for a round number, call 3,400; then 71,940 will contain $21\frac{1}{6}$, which per week will amount to $148\frac{1}{3}$; say, for soakage and evaporation of the canal per week, 150 locks-full.

According to the account of the four summer-months of the present year, viz. June, July, August, and September, there have past the summit about 250 boats per week, loaded and empty; those would generally require two locks-full to a boat: sometimes, indeed, they would pass alternate, so that two boats would pass with a lock-full; that is, reckoned for each side the summit, the amount would be a lock-full to a boat; but as this only sometimes happens, to allow for unavoidable waste, we may fairly reckon two locks-full to a boat: the expense, therefore, of lockage through the summit may be called 500 locks-full per week.

1st. The lockage of the Wolverhampton branch into the main trunk of the Staffordshire canal, is estimated at twelve boats per day loaded, and as many empty, that is, twenty-four locks-full; but the lowest lock at Autherly being a ten feet rise, will expend the same water as if they were all ten feet locks, and which will be equivalent to forty locks-full of six feet, such as the rest are, that is, 240 per week.

The account, therefore, with other intervening locks, will stand thus:—

	Locks-full.
To lockage of vessels through the summit per week, - - -	500
To ditto by the Autherly locks into the main trunk, - - -	240
	—
Total lockage per week, - - -	740
	The

	Brought over	Locks-full.
The soakage and evaporation estimated at	-	150
Leakage of locks-full per day, in each string, viz. one on each side the summit (one of which will supply the Wednesbury branch also), that is, eight per day,	-	56
Leakage of Autherly string, four ten feet locks will be two and two thirds more than common locks-full per day, that is, per week, eighteen and two thirds, say	-	19
Dead stock, or regulating water,	-	226
Total supply per estimate,	-	965

2dly. The supplies that furnished this business in the dry months of the summer, 1781, were as follows :

					Locks-full per day.	
The company's new engine at Smethwick,	-	-	-	-	565	
Ditto engine at Spon lane,	-	-	-	-	415	
						980
					Locks-full.	Butts.
The spring near the lock office, called Hadly's spring,					1	1
The springs, called G. Smith moor springs,					7	3
The Rood End springs,					46	0
Crosswell springs that feed Hill's mill,					115	6
						170
						1150
1. Lord Dudley's old engine,	-	-	-	-	127	
2. Brown and Co. Coastly moor,	-	-	-	-	54	
3. Bloomfield, the patent engine,	-	-	-	-	74	
4. Wilkinson's, at Bradley moor,	-	-	-	-	26	
5. Capon field new engine,	-	-	-	-	15	
Penn and Co's.	-	-	-	-	75	
Lane's,	-	-	-	-	33	
Tomkey's,	-	-	-	-	53	
Catchem moor,	-	-	-	-	19	
						478
						1628
But in this period, the canal had lost so much in depth, that the vessels could only go with burthens of seventeen tons, instead of twenty-four; so that having lost full twelve inches in depth, it would be expending from itself at the rate of, per week,						
						73
Total of the supply,						1701

N. B. The

N. B. The Thimble mill water and springs that used to be taken in to supply the great reservoir during this time were turned down to the mills; and hence it appears, that of the above supply, amounting to 1700 locks-full per week, only 170 of it was natural water supplied by springs, which is but one-tenth part of the whole, had the others been taken in, viz.

	Locks-full per week.
The Thimble mill springs,	45
Hanson's pool springs,	23
	68
To which add the western springs,	170 as before
The whole of the springs,	238 would make
but about one-seventh of the whole supply.	

3dly. From the two preceding statements we may draw the following:

	Locks-full per week.
Water furnished by springs,	170
Ditto by colliery engines,	478
by loss of depth upon the whole surface of the canal,	73
	721
Total of new water supplied to the canal per week,	
From which deduct the known consumption that never returned, viz. by	
lockage to Autherly,	240
By lockage of the Wednesbury branch, at one boat per day each way, will be	12
The known consumption that never returned,	252
The real weekly consumption of regulating water expended in the several ar-	
ticles of evaporation, soakage, leakage of locks, and waste,	469
The regulating water, as by computation preceding,	225
Weekly expense of regulating water more than computation,	244

Hence it appears, 1st, That the weekly waste of dead stock, or of regulating water, is full double to the computed quantity. 2d, That the real quantity, 469, is almost equal to 500. The quantity computed for lockage of the summit. 3dly, That the quantity of spring water actually taken in, viz. 170 locks-full, was not one quarter of 721, the quantity of new water wanted, beside the return of the company's engine, and had the whole of the springs been taken in, it would not have amounted to one-third of the whole supply of new water.

The

The quantity therefore produced by nature appears very inadequate to the supply of this canal in dry seasons; and therefore it is not to be wondered, that before the company's engines were built, the navigation was totally stopped in dry seasons for want of waters.

For with respect to the two reservoirs, they could afford no assistance in the case, as they would be exhausted before the pinch of the season came on, as we shall see must be the case, on comparing their contents with the weekly wants above stated.

The great reservoir at Smethwick, is computed to contain 1514 locks-full when full, but as I am informed, if full by the winter's rains, it will have lost eight feet of its top water, by the time it is wanted; but supposing it to lose only six feet, it will then contain but 621 locks-full: the rest of the reservoirs I understand hold water pretty well, and their capacities are computed as follows:

	Locks-full,
4th. Great reservoir at Smethwick, after losing six feet at top	- 621
Little ditto, near Mr. Hanson's	- 100
Tittford reservoir	- 500
Whole content of all the reservoirs	1221

Hence, if the company's engines were laid aside, and the summit to be supplied from the reservoirs at the rate of 500 locks-full per week, the whole, with allowance for leakage, &c. arising in this part (viz. fifty-six per week, as per first statement) would be consumed in fifteen days nearly; and with the assistance of all the springs coming in during the time in aid, the whole would be gone in three weeks, and then the canal would be left to subsist upon the springs alone in the manner before stated, and such casual showers as do not commonly happen in the four dry months of the year, to be of much service to such an extent of navigation.

From what precedes, it plainly appears how very inadequate not only all the springs, but all the reservoirs are, towards an effectual supply of the Birmingham canal with water: As it therefore must in a great measure depend upon artificial means, and as there do not appear to me any, but the same artificial means of restoring the water of the springs to those mills from which it is intercepted, it seems by far the clearest way, to dismiss all the waters of the springs, and suffer them again to take their natural courses: for though some advantage might be made in using those spring waters for lockage from the summit each way, and a method may be pointed out, whereby
precisely

precisely the same quantity of water may be let out from the level canals, extending from the foot of the Smethwick locks each way for the use of the mills, that was taken in at the summit; yet as I know no means of effecting this, but by a continual attention to the water gages, that must be constructed for this purpose, so that in all the variation of the influx, that of the efflux may be regulated conformably thereto; yet as a misapplication will always be in the power of the person attending, so as to give the mills either less or more than their due, this of course will often prove unsatisfactory; and as it appears, that the whole of the springs are scarcely one-third of the water wanted, and not one-fourth of the water raised by the company's engines, what supplies the two-thirds may just as well supply the other part; for when an engine or engines are once established, with proper persons to attend them at all times, as appears to me indispensably necessary, there is only the trifling difference in the quantity of coals necessary to do the whole work, or two-third parts of it.

We are now led to remark, that though engines can return the water from the lower level to the higher, so as to answer the purpose of lockage, and leakage of locks, yet since the returning engines cannot create water, what is lost by evaporation and soakage must be a sheer loss, that must be made good by the introduction of new adventitious water, to supply the place of what is gone: but towards the fund of supply, the water of the springs cannot be applied, because what sinks into the earth, and mixes with the atmosphere is lost to the mills, as well as to the navigation, and if to be supplied elsewhere, or otherways, what will supply the mills will supply the navigation.

It has been already stated, that the quantity of regulating water, or waste of the dead stock weekly, amounts to 469 locks-full, which, together with what is necessary for the lockage to Autherly, and down into Wednesbury branch, viz. 252 locks-full more, make the whole amount of new water into the Wolverhampton canal, to be 721 locks-full per week.

Now it has been remarked, that the 469 locks-full of regulating water, actually lost, being full double of what might be expected according to my ordinary computation thereof, this is a reason why the more suspicious parts of the canal should be searched, in order to try to stop the leaks: yet as the quantity of soakage depends in a great measure upon the nature of the soil through which it passes, and though in making a computation for the supplies of a canal, as the loss by soakage will always be something, and in some soils may be a very great quantity, and therefore some kind of allowance must be made for it; yet as it is out of all human power to foresee

or

or say before hand, what it will be in the particular cases, in this respect when a canal is made, calculation must submit to the experience of the particular situation, and therefore when the fact greatly exceeds the computation, it is, as has already been said, a good reason for looking out and examining: yet after all, any difference that we may find, may be owing to the nature of the soil; and indeed, when we consider that many parts of the Wolverhampton canal, in passing through the colliery grounds for considerable spaces together, pass over those from under which the coal has been worked, and in several places the canal actually let down, so that the sides need raising to an additional height, on that account we are not to wonder at extraordinary leakages; nor even if it shall prove, that these extraordinary leakages are incapable of remedy; so that a canal in such a situation, being subject to these derangements, I cannot hold it in a safe situation, unless it can command a considerable redundancy of water beyond all calculation.

For these reasons we cannot reckon a less quantity of new water necessary to uphold the navigation in its present state, than what we now find, viz.

	Locks-full per week.
5th. The nine colliery engines supply as before stated	- 478
And if you take the springs amounting to	- 238

You have nearly the quantity 716

But as there are several colliery engines that raise, and are likely to raise, considerable quantities of water that might go into the canal, that now do not, as it will be their real interest so to do, so it will be your interest and advantage to lay such reasonable inducements before the owners of those collieries, as shall make them ready to support the canal, with all the water in their power.

Account of engines that actually raise water that would go into the canal, but which is turned another way.

	Locks-full per week
6th. Tomkey's executors (late Wilkinson's)	- 107
Ditto next beyond	- 120
Barber's upper engine	- 56

Water that may be had 283

To which add the nine engines that now supply the canal - 478

Here then is plainly a surplusage beyond what is found to be wanted of forty locks-

full - 761

Brought over - 761

In further aid, to stand against such accidents as may happen amongst the engines, it seems proper that the company should raise the water into the canal, that is now delivered by Bickley's new engine upon the surface, which, though considerably below the level of the canal, may be done by an engine of the smallest size; the water of this engine amounts to

122

Total recommended for present service 883

Total wanted for ditto 721

Overplus 162

Besides the above, the waters of the three following working engines might be lifted up into the canal, if occasion required, that now being delivered below it, take their course a different way.

	Locks-full per week,
7th. Aston and Co.	12
Dall's hole	90
Barber's low engine	14

Further supply 116

It is very natural for the mind to suggest, that though the whole number of working engines may be at present fully sufficient to keep up the dead stock of regulating water for the canal, and also the Autherly lockage, yet, as the collieries are daily in a state of change, and successively working out, it may happen in time, that being wrought out, and ceasing to draw water, the canal may fail of supply: but in answer to this it must be observed, that so long as Birmingham, Wolverhampton, &c. are wanting coals, new collieries will be opened for their supply, which will afford new quantities of water; and for this reason, I have brought to account only those colliery-engines that I found actually at work, reserving those that were building; and those that may probably work in a short time, to balance those that may not long continue at work, on account of the fields of coals being worked out, for which they were built. The following is therefore a list of such engines as probably will work in a short time, with the quantity of water they may be expected to afford at twelve hours work per day, viz.

Hancock and Co.'s new engine	63
Lord Dudley's new engine	79
Fownes and Co. the engine stopped on account of the coal being on fire, but water putting in to extinguish it	50

Expected supplies 192

N. B. Hancock and Co.'s seems intended to deliver into the canal, the other two will deliver below it, but being at no great distance therefrom, can be lifted into it by the smallest engines.

The following contains an account of such other waters as have been pointed out to me as a supply, viz.

	Locks-full per week.
9th. Manmoor Green, a colliery formerly worked here, whose out-burst	31
Broadwater, a colliery formerly worked, whose out-burst here	57
Ditto Sparrow's Forge	166
Total of Broadwater's out-bursts	223
Total supply of collieries out-burst water	254

Now it is to be remarked, that it is the greatest part of twenty years since the two collieries above mentioned ceased working, and that the whole of the out-burst water goes to the supply of Gasbrook mill, near Autherly, and in dry seasons is a material part of the supply of that mill. The out-burst, near Broadwater, goes to Willingworth Hall mill, and, in dry seasons, is a considerable part of its supply; and the out-burst that goes to Sparrow's forge near to Wednesbury (which is by far the most considerable) is the whole supply of that work.

If the water of Broadwater colliery waste were drawn by an engine to a proper depth, I doubt not but it would bring to it the greatest part, if not the whole of the water of the out-bursts, amounting to 223 locks-full per week, and drawn at a greater depth, doubtless the feeder would be increased; but we may be sure it would not be much increased, because from the remains of the old engine at Broadwater, its size and powers may be gathered, and from the reputed depth from whence it drew, the quantity may be nearly estimated that it could do, which only moderately exceeds the quantity now given by the out-bursts.

The Manmoor Green water may also be drawn by an engine put down to a greater depth than where it issues, and its feeder might also be probably increased, in what degree is uncertain; but as the quantity now given is a mere trifle when applied to the purposes of the canal, and the engine, by the accounts of it, was a small one, no quantity of water of consideration can be expected here; and indeed, as both the waters of Manmoor Green and Broadwater have been so long occupied by mills, though it may not amount to a legal prescription against the inheritors of the freehold, yet being in possession thereof at the time of passing the Birmingham Canal Act, I must

must submit it to the gentlemen of the law, whether, as respecting the canal, they would not stand upon the same grounds as other mills, as to a restitution or recompense for loss of water: and in case of application to parliament for any new powers, they would (I speak with all due submission) doubtless, on petition, prevent the water being taken without a recompense; and therefore would then be established upon the same grounds as other mills possessing their water by a more ancient prescription.

But supposing the whole of the natural waters that I have viewed, exclusive of the colliery engines, were collected for service, they would stand thus.

	Locks-full per week.
10th. The springs - - - - -	- 238
Manmoor Green and Broadwater out-bursts - - - - -	- 254
	492
The company's reservoirs, supposing 1221 locks-full, equally expended during the four summer months, they will amount to per week - - - - -	- 70
And supposing the canal itself to be lowered six inches, which I suppose it might be without considerable prejudice, this will amount per week to - - - - -	- 36
	106
Total collection, exclusive of colliery-engines - - - - -	- 598
Quantity wanted - - - - -	- 721
Deficient - - - - -	- 123

It has been suggested, that each of those colliery wastes may be capable, exclusive of their natural feeders, as comprehending a quantity of hollow ground from whence the coal has been worked, of containing a great quantity of water as reservoirs, to be filled yearly by the winter's rains, which, being drawn out into the canal during the summer months, without defalcation from evaporation, or soakage, will afford a material supply of water to the canal, when it is most needed.

How far at this time these hollows may exist, is altogether problematical; for the coal wrought at Manmoor Green, was what is in these parts called a thin seam, that is, six or seven feet thick; and though there is not much appearance of falls from the surface, yet the under strata may be so broken, and shivered, as to fill the bulk of the cavity: besides, if this coal rests upon that kind of stratum of clayey stone, which is usual for the coal to rest upon in other parts of the kingdom, and called by various names,

names, in this length of time it is probable, in like manner as in other places, that the pillars, by sinking into the foal, fill, or thill, the roof and foal may be so nearly come together, that but little cavity remains.

At Broadwater colliery, being upon the thick seam, the surface itself appears in many places so broken, that I have no doubt, but that a great part, if not the greatest part, of the cavity is already filled up: but if it were to happen that the Birmingham canal were to be much pressed for want of water, then it might be worth while to try those expedients; and if we suppose each of those wastes of equal capacity with the whole sum of the reservoirs the company now have, viz. to furnish seventy locks-full per week each, that is, one hundred and forty locks-full the two, then this will exceed the deficiencies last-mentioned, by seventeen locks-full.

11th. The whole of the supplies of new water taken together that it seems at present practicable to procure, is as follows:

	Locks-full per week.
By springs into the summit	238
By nine colliery-engines, now delivering into the canal	478
By three ditto, that may deliver into the canal, but do not	283
By one ditto, that cannot deliver, but recommended to be made	122
The supply recommended	883
By three engines that cannot deliver into the canal, but might be made to do it, if occasion required	116
By Manmoor Green, and Broadwater out-bursts	254
By the company's reservoirs	70
By six inches of the canal as a reservoir	36
Visible waters that may be procured	476
By problematical waters that may possibly be procured from Manmoor Green, and Broadwater wastes	140
Total of waters that appeared to me capable of being collected	1737

Besides all which, as the springs into the summit amount only to 238, whereas the quantity wanted there (as before stated) is 556; the difference, 318 locks-full, would be required to be raised by the company's engines, and would be near upon the work of Spoon-lane engine.

The whole of the above statements being carefully considered, it will clearly appear, that though it may be laid down as a practicable thing to supply the present demands of the canal with water, yet it cannot be done otherwise than by taking the greatest part

part of it from the mills that were in possession of it before the Birmingham canal was made; besides the supply of a considerable part by the company's returning engines. Now, as there appears a sufficiency capable of answering all probable contingencies, by means of the full use of the company's engines, and a judicious application of the colliery-engines' water, it cannot be doubted, but that the supply of the canal by the latter means will be the most eligible.

It may be said, indeed, suppose the owners of the collieries should refuse to deliver their water into the canal, but on such terms as might make it dearer to the company even than paying the millers their full value? I beg leave to suggest what on other occasions I have been assured of; viz. that no man can acquire any property in water, otherwise than in regard to the use he makes of it; and therefore I conclude, that though the colliery owners may, at their own choice, deliver their engine water into the canal, or into a water-course that will naturally lead it under, or away from the canal, yet that the canal company may, in preference of all others, take it up again, and raise it into the canal, before any third person has acquired any property therein.

Respecting the proposed extensions of the canal.

1st. With respect to the extension from New Hall Ring to Deretend and Bordsley, I have already remarked, that it appears to me very judiciously laid out to conduct the navigation to the points referred to; but it will appear from the preceding statement, that it can have no water for lockage, but what is the result of a rainy season, which may probably be, *communibus annis*, about four or five months; that is, when all the mills in general have a superfluity of water, and therefore, that a fire-engine in some proper place near New Hall Ring, with a tunnel to conduct the water thereto, will be necessary to be established along with the canal itself; for if the whole of the natural supply at the summit were to be used, it is probable it would not do more than supply the lockage of this branch, and then it will be wholly taken from the mills; for though this water were used to lock from the summit down to the present level canal to Birmingham, yet, if its equivalent be let out by gages to the mills, then this water would be wholly taken away from the lockage of this extension; but there is no doubt of its being effectually supplied, by returning the water by an engine.

2dly. With respect to the extension of the Wednesbury branch to the coal grounds lying upon a lower level towards Bilston and Darlaston, the ground also appears to me judiciously chosen to conduct the canal through this district to the points required, and
except

except some deep cutting to the north-westward of Broadwater old engine, there does not appear any part of the work likely to be attended with any particular extra expence: but here again, as the lockage water from the summit is returned from the Wolverhampton canal back again to the summit, here will be no water to lock down with, into the lower level, except the surplufage of the Wolverhampton canal supply above its ordinary confumption of regulating water, that is,

	Locks-full per week.
12th. The supply being stated - - - - -	883
The water wanted for other stated purposes - - - - -	721
There will remain for lockage to the lower level - - - - -	162

but as this will only lock eighty-one veffels, it is plain this is not to be fecurely done without a returning engine, to lift the water back into the Wolverhampton level; and for this purpose nothing can be better adapted than the propofed fituation at Oker Hill, which will in reality be attended with feveral material advantages.

This propofed extension, with its branches, will meafure about feven miles, which being about one quarter part of the prefent canal, will require for its evaporation and foakage waters about one quarter part of what the prefent canal requires, which being computed to be 469 locks-full per week, one-fourth of this will be 117 locks-full per week; but the overplus being 162, it appears that there will be a fupply of regulating water for the canal, in this firft inftance, and fomething to fpare for lockage. And when collieries are opened upon it, being intended for their immediate fervice, they can think it no hardship to fubmit to a claufe, obliging them to turn all fuch engine water into the canal as is delivered above its level, and that the company be at full liberty to lift all fuch into the canal that they fhall judge proper, and in confequence it is not to be doubted but that a quantity will be procured, not only fully adequate to the regulating water of this extension, but which, by means of the engine at Oker Hill, may be brought in aid of all fuch deficiencies as may happen upon the prefent lines by the working out of the collieries now there; and thus the whole work be permanently eftablifhed.

Refpecting the expediency of a new canal.

A new canal being faid to be at this time in agitation, propofing to take up coals from the fame diftrict of country, between Wednefbury and Oker Hill, where the
Wednefbury

Wednesbury extension of the Birmingham canal is proposed to pass, and to conduct them by a different passage to the skirts of the town of Birmingham, near Deretend; and from thence away to Fazely, to join the line of the proposed canal, from the main trunk of the Staffordshire canal, at Fradley Heath, to Coventry, and so to Oxford: As a person consulted by you, it will be proper to subjoin some remarks upon the operation and expediency thereof.

And in the first place I must observe, that what may be the necessity or expediency of conveying the Wednesbury coals to Fazely, that is, to the line of the Coventry canal, or the profits attending such conveyance, I pretend not to judge; but, whatever they might be, considered in this single point of view, they will undoubtedly turn out to be the greater, by the work itself being done upon the most direct and practicable line, and at the least expense, this being the obvious way to make a productive scheme.

What the line may be that I am told is in contemplation, I cannot completely judge of till the proposers have published their scheme, but this I observe, that the country lying between Wednesbury and Birmingham, after quitting the valley of the river Tame, in order to get thither by way of Aston, &c. is very uneven, not naturally adapted to the course of a canal, nor yet such as that a canal can be adapted to it without incurring very large extra expenses; whereas, upon supposition that the principal object is to make a navigation from Wednesbury to Fazely, nothing can be better adapted in point of ground, through so long a course of country, than to pursue the course of the river Tame, which might be done either by conducting a canal by the course of the river's valley down to Fazely (in the whole course of which there seems nothing material to hinder) or by making the river itself navigable; or perhaps by what will be found the most eligible, practicable, and cheapest mode of all, to do it partly by one and partly by the other; that is, to make a canal where the river does not suit, and to take the river where it does. To do this by way of Salford bridge (about three miles from Birmingham) there is no natural impediment, on supposition of a competency of water.

But in lieu of a proposition so plain and evident, to take the canal out of the valley of the Tame, through every impediment, and by a much longer course, to the skirt of the town of Birmingham, and then from thence to return back into the valley of the river Tame to go down to Fazely, can certainly be intended for no other purpose than that of sharing the profits with you, that arise from the carriage of coals from the

the district of Wednesbury, for the supply of Birmingham, in which article I would presume that the greatest part, if not the whole of the profit of your undertaking consists.

When it is considered how many canal schemes have been abortive, how many more have fallen short of paying common interest of the vast sums of money expended upon them, in proportion to those few that have succeeded, so as to become profitable; and when it is further considered, that the few which have succeeded, have been successful in consequence of some favourable circumstances occurring, either wholly unforeseen, or not seen in the light of the capital articles of profit, which they have afterwards turned out, we must conclude, that were it not that some have proved successful, the spirit of canal making that a few years since even raged amongst us, would be wholly extinct, and the public be deprived of the advantages further to be derived from this kind of enterprize, by which it is already found to be so largely benefited. For if in those successful cases, the proprietors are by an act of legislature defeated in the profit they have so dearly earned by a partition, the whole of the real motive for this kind of enterprize will be totally abolished; for in case it were possible in reality to turn out a sufficient inducing profit for two, a third has an equal right to thrust in, and after that a fourth upon the same principle.

A canal has been granted running parallel to a former established navigation, but then it was where expedition and cheapness of carriage were not only offered, but insured on terms not even in any degree met by the old establishment. A canal, in a similar situation, has also been refused, though proposing greater expedition and lower terms of carriage; but the practicability of materially lowering the carriage, consistently with the necessary profit to keep the works alive, not being fully proved; and the whole proposition being met by the old proprietors on reasonable grounds, it was judged better fully to establish one, than put them both to hazard: and in both these cases, the water possessed by the former navigation was held sacred, though each of them had a large river for their supply. Much more might be said upon the above heads, and painted in stronger colours; but it comes more within my province to state the mechanical difficulties that seem to me likely to attend the establishment of a double navigation in this place.

It is principally to be remarked, what has already been clearly shewn, viz. that the Birmingham canal, not only is now, but of necessity must be in future, supported by artificial means; and that this canal, independently of any one article of business done upon it, requires supporting with a dead stock of water, whose weekly consumption, or waste, amounts to no less than 469 locks-full per week; and that to do their business

upon the present establishment, they necessarily require (besides the return of almost 1000 by the company's engines) 252 more, making in the whole, 721 locks-full of new water; that the whole quantity the Birmingham canal can readily command, does not exceed 883, and that is no more than necessary to have a reasonable security of having enough: yet, supposing us to calculate to a single lock-full (a task I can by no means engage to perform)

	Locks-full per week.
The exceedence here will be only	162
To which, if we add the only water that would turn off from the engines, that need not be taken up at present for the supply of the Birmingham canal, viz.	
Aston and Co., Dall's hole, and Barber's lower engine	116
The whole amount of overplus would be no more than	278

Now, if a canal of equal extent with that of Birmingham, or greater, were executed, we must expect it to require as much, or more regulating water, and lockage water, in proportion to its business. It therefore appears, that if after the Birmingham canal is barely supplied, there is not much above half as much regulating water as it must reasonably be expected to want; and if the new canal finds means to procure a part of that water which would have been drawn out of the earth, and fed the present canal, then there will be two companies depending upon the same joint stock of water, and there not being enough for both, the consequence would be, that both would greatly suffer: for if a new canal be supplied with 278 locks-full for regulating water, that should have 469, there will be a deficiency of 191 locks-full; and if only half of this deficiency were deducted from the old canal, so as to create a deficiency of ninety-five locks-full per week, the very ill effect that must necessarily attend, this will appear from what was experienced in the summer of 1781, for the want only of seventy locks-full more than they were then supplied with, had reduced them a foot in depth upon the whole canal, and obliged the boats to go with such short loadings, that three boats were employed to do the business usually done by two; and had they been deficient ninety locks-full per week, the navigation must have been wholly stopped for want of depth of water in the canal, notwithstanding the power of the company's engines to return the lockage water.

It further appears, that the new canal must be in the same predicament respecting the being supported with artificial water, as the present one; for it cannot be supposed to acquire any more right over the mill waters, without restitution, than the other; and therefore the out-burst waters of the Broadwater colliery waste cannot be applied in aid of the new canal without the same inequality and injustice as to the present one.

one. It may be suggested, that as new collieries will be opened in consequence of a new canal, new waters will be raised by those new collieries towards its supply; but as the consumption of coals at Birmingham, can only be of a limited quantity, the question will be, whether they can be more effectually carried by two canals than by one, that is, when they are both to subsist upon the same original stock of water?

A certain produce of coals, or, if I may so say, a certain number of collieries, are sufficient for the supply of Birmingham: if new collieries are opened upon the new canal, the same number less will be opened afresh, or continued upon the old; the water therefore drawn, that can be brought to supply the old canal, will be diminished by the quantity brought into the new, and since the regulating water of the two canals, will be doubled, and without carrying a coal, will be nearly equal to the quantity that will effectually serve the old one in the highest state of business in short water seasons; it therefore follows, however paradoxical it may at first sight appear, that one canal may do a great quantity of business with the same water that would barely supply the waste of two.

It perhaps may be urged by those who would favour the new scheme, from a slight consideration of my eleventh statement, which is intended to shew, that 1737 locks-full per week, is the utmost that can be obtained by an entire sweep and command of all the waters in the country which can be brought to bear, that is, without paying any regard to the rights and uses of mills now established; and therefore that this quantity divided between the two canals, that is, 868 to each, will be almost as much as I have recommended at present to be taken in, as a full supply for the now subsisting canal, viz. 883, as per sixth and eleventh statements, and more than 721, which I have ascertained to be the present necessary supply of it; yet when all the waters are deducted out of that account, that are either perfectly problematical, or already appropriated to working mills (which I apprehend to be fully as useful to the manufactures of the country as the canal itself) the overplus remaining will not exceed 278 locks-full, as before stated, even when the Birmingham canal is reduced to the bare subsistence of 721 locks-full per week.

How very hazardous it must be to the present subsisting undertaking to be circumscribed in such a narrow manner, which, going over many tracts of hollow grounds, that now contribute to make it take double the quantity of regulating water that it might be expected to do, and which will every day be increasing, must appear to every judicious person; and if it be further considered, that besides the 721 locks-full
ascertained

ascertained as above, and also, that there is a necessity for the company's returning engines, which raise no less than 980 locks-full, making in the whole 1700 locks-full per week, equal or nearly upon to the full amount of the whole country's produce, it will clearly appear, that if even this whole produce were divided between the two undertakings, that the new one would have an equal necessity to apply to returning engines, and as these would be necessary in the first instance, they would very greatly embarrass an infant project.

Having gone this length, I conclude, that it must appear to every judicious person who considers and weighs the above statements and premises, that the part of the country in question does not in reality afford the quantity of water whereon to subsist two canals, even after all artificial means are used, with the best management of the water that nature produces; and furthermore, that which is likely to be fully sufficient for one, will be an apparent ruin to two; nay, even if the scheme were confined to the single purpose of carrying coals to Fazely, as above pointed out, which, though it would no ways interfere with the present company in point of trade, yet as the regulating water that it must subsist upon being drawn from the same sources, would evidently put the resources of the present canal in obvious and imminent hazard. I must therefore conclude with suggesting, that if a canal from the Wednesbury collieries to Fazely be in reality necessary, it can be done to the best advantage by carrying forward the new proposed extension of the Wednesbury canal, by way of Walsal and Shenton to Fazely, which being a course as I apprehend shorter by more than one half, the quantity of regulating water will be very greatly less, and I apprehend the additional collieries for this service would be more than adequate to the leakage, but till this course is surveyed and levelled, I forbear to speak further of it.

J. SMEATON.

Austhorpe, 16th December, 1782.

BUDE HAVEN CANAL.

The REPORT of JOHN SMEATON, engineer, upon the practicability of a canal proposed from Bude Haven to the river Tamar, at Calstock, in the county of Cornwall.

HAVING viewed the country through which it has been proposed to carry this canal, and remarked the leading circumstances relative thereto, I have no doubt but that a canal is, physically speaking, practicable in the course that has been chalked out, and by means of such kind of engines and machines as have been contrived and proposed by the ingenious Mr. Edyvean; but how far it may be eligible and useful in point of expense to execute the whole, or any part thereof, or in any other different line or mode, which is the subject of the present question, can only be known by a careful investigation of the expense, when turned in every practical point of view.

The county of Cornwall, in general, seems but ill adapted for the making of canals across the country, being so very frequently intersected with valleys, that to preserve a level for any considerable space between two given points, it becomes necessary to go through a vast meandering course, inasmuch that in the present case, where the distance between Bude Haven and Calstock is under thirty miles, the course chalked out for the canal, supposing it to ascend the smallest perpendicular between the two seas, at a place, on this account, called the Pack-saddle, will be above ninety miles in length.

The time allotted to look over this extensive course, with its collateral circumstances, being but seven days upon the ground, did not admit of the taking particular surveys, levels, and dimensions; and indeed to have done that fully and satisfactorily, would have taken as many months as I spent days upon it; but this, in fact, would have been a waste of time, because to have gone into accurate admeasurements of such schemes, that must in all probability be rejected, when at the same time the merits of the question are capable of being brought into a narrow compass, would indeed be spending time to no purpose. For this reason I have contented myself with viewing the general line and face of the country, which, assisted by the actual measures taken, and observations made by Mr. Edmund Leach, who was desired to attend me upon this view, and who has since communicated to me, not only the measures of lengths and proposed dimensions of the canal, but many other judicious observations on these grounds, assisted
by

by my own experience, of the probability of what is likely to happen in the execution of such a kind of work in a country so constituted, I have been able to bring together into one view comparative estimates of the different modes that appear to me the most likely to take place in the present case, from whence it may be judged by the well-wishers to, and promoters of this scheme, which is the most likely to be adapted to the capital that is practicable to raise, and which is most likely to pay interest for the capital so advanced, or what is, as I apprehend, the same thing, likely to be, upon the whole, the greatest advantage to the country; and if it shall appear that any of the five modes that I have particularly investigated, shall be eligible to be put in execution, then I would recommend the tract so chosen to be more particularly and carefully surveyed, levelled, and dimensions taken, from whence an estimate may be made of particulars that may be expected to come somewhat near the real expense which will be incurred, and as I apprehend, that, in any of the ways, an amendment of the act of parliament will be required, I have, therefore, no ways confined my views to the limits thereof.

The materials that I have chiefly made use of from the communication of Mr. Leach, are as follows.:

1st. The measures of lengths of the different districts or stages, upon the line of the canal, as he measured them, being in the whole, according to his original survey from Bude Haven to Kelly Rock, upon the Tamar, in the parish of Calstock, ninety-one miles.

2d. The dimensions of the canal proposed, viz. twelve feet bottom and four feet deep, digging from three-pence to sixpence, but at an average four-pence per cube yard.

3d. The value of the lands, which he observed to be at various prices, worth from five shillings to forty shillings annual rent, and averaging the quantity of each sort, with the quality, he makes the value of the whole at fifteen shillings per annum; which, at thirty years purchase, will be twenty-two pounds ten shillings per acre.

4th. The quantity of sand and lime likely to be carried annually upon the canal, wherein he observes, that the distance between Bude Haven and Kelly Rock, in a right line, according to Martin's map, is twenty-eight miles, and he supposes that an equivalent surface to that of five miles on each side this direct line, that is, a surface of twenty-eight miles long, and ten miles broad, will receive benefit from this canal; in consequence,

consequence, 179,200 acres of land will be concerned therein, of which he supposes one-twentieth part, that is, 8960 acres yearly, to be broken up for tillage.

He supposes further, that one half of this, viz. 4480 acres, to be manured with sand, and the other half with lime, and that the value of the carriage of each may be estimated upon what it is at Launceston, which is nearly half-way between the two extremes.

That the usual quantity of Bude or Widemouth sand, to an acre, is sixty horse seams, and weighs about eight tons, which costs in land carriage to Launceston three pounds, but he allows ten tons to an acre and one-third, which is nearly the same proportion.

The usual quantity of lime laid upon an acre is 100 Winchester bushels, weighing about $3\frac{1}{4}$ tons, the land-carriage of which to or near Launceston is one pound sixteen shillings, this will be ten tons to three acres.

Upon these foundations, which are sufficiently distinct, and of which every gentleman will be enabled to judge, perhaps better than myself, I have proceeded to form the comparative estimates before mentioned, according to five different propositions for executing a canal, and which are contained in five schedules, accompanying this report; and as the merit of the question is chiefly contained in what arises from these schedules, what I have further to remark will most properly come in by way of explanations, observations, and abridgements of these schedules.

Schedule first contains the estimates and result of the original propositions for making a canal from Bude Haven to Kelly Rock, by way of the Pack-saddle, and by means of five engines, as proposed by Mr. Edyvean, for transferring the cargoes from the level of one canal to that of another, without the use of locks. The whole length from Bude to Tamar, at Kelly Rock, being ninety-one miles, and from Bude to Launceston forty-nine miles, by the course of the canal.

The estimated capital for the execution of this work is £119,210, and the capital that is likely to be supported by the tolls upon sand and lime is £145,192, which exceeds the former by no less a sum than £25,990; and hence, upon the first face of it, it would appear to be a practicable scheme; but it must be considered and remarked, that the estimate of the expense, as it stands, is the least that, from the nature of the country, can happen; and that there is no allowance for some deep cutting through considerable

derable rising grounds that occur, notwithstanding so very long a course to avoid them ; but, exclusive of these considerations, the exceeding sum being but twenty-two per cent. upon the sum estimated (at the very lowest) to be wanted ; this seems inadequate to the risk of a greater cost, or less profits, or both, and also that of keeping the whole in repair ; for though the articles of the carriage of coals, culm, wood, timber, iron, lime for building, corn, merchandize, &c. are not taken into the account, yet, if the profit of all these articles put together, will pay for their overseers of the repairs of the works, their clerks, toll-gatherers, &c. it will probably be as much as the tolls upon these articles will produce. As the plan thus circumstanced does not therefore appear to me eligible to the adventurers as it stands, we will now attend to what is stated in the next schedule.

Schedule, No. 2, contains the estimates and result of the same propositions shortened, in point of length, between Bude and Launceston, by carrying the canal over Greena Moor, as pointed out by Mr. Call ; which course having viewed, I found the same practicable, and by which means a very long meandering course, up the valley of the river Altry, and several included valleys, will be avoided ; and, by which means, according to Mr. Leach, there will be cut off fifteen miles from the length.

In this tract, as Greena Moor lies considerably higher than the ground at the Pack-saddle, an additional lift will be required into the canal of Partition, and another engine to drop down into the former level, or works to avoid them, in all probability, of equivalent charge. I have, therefore, computed the expense on this supposition, for as the lowest land between Treneglofs and Lancaſt rises still much higher than Greena Moor, I see no probability of a passage that way upon the same level, a circumstance recommended by Mr. Call to be adverted to.

The total length, therefore, by Greena Moor, being reduced to seventy-six miles, and the distance between Bude and Launceston to thirty-four miles.

The estimated capital is reduced to	-	-	-	-	-	£102,087 and
The capital supposed to be supported by the tolls,	-	-	-	-	-	146,971

The difference by which the estimated capital is exceeded by the capital supposed to be supported,	-	-	-	-	-	44,884
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that is, forty-four per cent. upon the estimated capital.

This

This being double per cent. upon the former, looks much more like business, but yet, in affairs of such great uncertainty, it may be adviseable to look further.

Schedule, No. 3.—Suppose the northern part of the canal only to be executed, that is from Bude to Launceston, upon Mr. Leach's original plan,

The total length then being forty-nine miles, the estimated capital will be reduced to	£65,228
And the capital supposed to be supported by tolls,	83,440

The difference, or excess of the capital supposed to be supported above that estimated,	
will be	£18,212

that is, twenty-eight per cent. upon the estimated capital.

Hence it appears that, compared with schedule, No. 1, the execution of the northern part of the canal, from Bude Haven to Launceston, is a safer adventure than that of the whole, and consequently a much better adventure than the execution of the southern part from Launceston to Calstock, but yet it appears that the execution of the whole, upon Mr. Call's plan, will be a better adventure, but a much greater capital, than this; we will, therefore, next see what will come out from a partial execution of the canal upon Mr. Call's plan.

Schedule, No. 4, contains the state of the case on supposition of executing the northern part of the canal from Bude Haven to Launceston, by way of Greena Moor, according to Mr. Call's plan.

The total length thereof is thirty-four miles, and the estimated capital thereon will be reduced to	£48,114
The capital supposed to be supported by tolls,	84,490

The difference or excess of the capital supposed to be supported above that estimated, will be	36,376
that is, the exceedings are seventy-six per cent. upon the estimated capital.	

We are now arrived at not only a moderate adventure in point of capital, but a great probability of tolls answerable to the risk. Yet, as the great object appeared to be the bringing of Bude sand into the heart of the country, whether to Launceston or elsewhere; when I came into the valley of the river Tamar from the Pack-saddle, and observed how gentle its decline was, how easily practicable for a canal by locks, as far as the eye could reach, in comparison with the very long meandering course that resulted from

keeping the level; I was tempted to take a further view of the valley, and found that from the point opposite the Pack-saddle, down to Greston bridge, it continues quite open, and very practicable for such a canal, and its decline is so easy, that for that length, as it appeared to me, a very moderate number of locks would make good the descent, and carry the vessels three or four miles further south than Launceston, to which place, if thought necessary, a branch canal may be carried up the valley of the Kenzie river to the bridge between Launceston and St. Stephen's. Finding this length down to Greston bridge so practicable, I was induced to examine the whole of the valley down to Calstock, to see whether there was any, and what, natural impediment to the making a navigation to the tides-way at Calstock, in case the same should hereafter be found expedient; but I found none to the making of a navigation upon the bed of the river, in the ordinary way of making rivers navigable by means of locks and dams, there being every where flat ground on one side or the other, one place only excepted, under Hingston Downs, which continues for so short a length, and the fall so easy, that a dam erected below this place would pond the water above it, so as to continue the navigation through it. Mr. Call also pointed out the eligibility of making the gently declining valley of the Bude river navigable by locks, to the foot of the steep rising hills; now, this being done from Bude Haven to the foot of Longford Hill, then ascending by engines and canals to a canal of partition at the Pack-saddle, as per No. 1, and then down to the locking canal of the Tamar valley to Greston bridge; this not only appeared the shortest way of bringing the Bude sand into the heart of the country, but seemed to be attended with far less risk and uncertainty of expense, as well as likely to be executed for the least original capital; and this has induced me to lay before the promoters of a navigable communication from Bude, a statement also of this matter, follows:—

Schedule 5, contains the result of a scheme for executing a canal, partly by locks and partly by engines, up the valley of the Bude river, and from thence across the Pack-saddle into the valley of the river Tamar, and down that valley to Greston bridge.

The estimated capital,	£46,108
The capital supposed to be supported by tolls,	94,150
The difference by which the estimated capital is exceeded by the capital supposed to be supported,	48,042
that is, exceeding by one hundred and four per cent.	

Here

Here the capital supposed to be supported, being more than double the capital estimated, affords every reasonable assurance of a successful enterprize, so that were the exceeding cost and the falling short of the tolls, to be very great, yet it is likely that on this principle there will be a sufficiency to pay the interest. Indeed there is one article of the estimate of the expense, upon this scheme, that wants supporting by actual measures; for, with regard to the level between the point of the Tamar, opposite the Pack-saddle, and the surface of the river at Greston bridge, I can only judge of it by estimation; so that it is as possible that it may need more than ten locks, as that it may be done with less; yet, when it is considered that this canal takes in about four miles in length more of the interior of the country, to compensate for four miles next Bude Haven, whose sand will scarcely come upon the canal, except to those who lie immediately thereon; I say, this being considered, and also that by going four miles nearer the lime country, a quantity of that article will be brought to the canal by land carriage to go north, and that the expense of even three or four locks more, would make no very material enlargement of the estimated capital; this appears to me to be the most secure and eligible scheme, and if so thought by the promoters of the canal, the actual taking of this level would put the affair out of doubt.

In regard to the expense of continuing the navigation by the bed of the river from Greston bridge to the tides way at Calstock; for want of levels I can scarcely guess at it, but I am satisfied, that it may be done that way, from Greston bridge, for less money than it can be carried in any other way from Launceston to Calstock.

If this mode of execution should be adopted, I expect that on a re-survey it may appear practicable to pierce the hill at the Pack-saddle, and to go upon a level from the Tamer into the valley of the Bude, till by one single lift or engine this canal may be joined with the locking canal in the Bude valley, and thereby all transferring of the cargoes avoided, except only one; but this must depend upon a more minute inspection of particulars, the estimate now made depending upon nothing but what I know the ground will really admit of.

It has been a question, whether machines in the manner proposed by Mr. Edyvean, or of any other similar construction, would do the business with sufficient dispatch, that is, whether one machine would do at each lift; but on computation from what I have already done in the way of drawing coals by water, I have no doubt but that the cargoes may be changed without the least hurry, at the rate of one ton in four minutes; so that a cargo of twenty tons will be changed in one hour and twenty minutes; and if 1680 cargoes are carried

carried annually in forty weeks, six days to the week, that will be seven cargoes per day, which will be changed in nine hours and twenty minutes.

I have only further to remark, that if £2. 16s. 0½d. be allowed to the consumer for carrying a cargo sideways from the canal, if Bude sand is carried from Bude to Launceston, fourteen miles according to the direct line, exclusive of the crookedness and inequalities of roads, for £7. 10s. as has been stated in the schedules; this £2. 16s. 0½d. would carry it 5¼ miles in a direct line sideways, which makes good the original supposition of taking in a space of five miles broad on each side, whereas any less allowance to the consumer would not do it.

J. SMEATON.

Austhorpe, 8th Jan. 1778.

SCHEDULE, No. 1.

Probable ESTIMATE for making a canal from Bude Haven to the river Tamar, according to the measures designed by Mr. Edmund Leach.

The bottom width twelve feet, and four feet depth, length ninety-one miles.

ESTIMATE of work per mile.

The bottom width being twelve feet, the slopes should be as three to five on each side,	£	s.	d.
this, upon four feet depth, will contain, per mile, 14,600 cube yards, which, at four-			
pence per yard, will amount to		243	6 8
Allow for banking up hollow places, and extra cutting through uneven grounds, hard			
matter, &c. one half the above,		121	13 4
The common width of ground over all, including cut and cover on both sides, for a			
canal of the above dimensions, will be about seventy-six feet, which will contain			
921 acres per mile, which, valued at the mean price of fifteen shillings per acre			
annual rent, and thirty years purchase, according to Mr. Leach, will be £22 10s.			
per acre, purchase, and per mile,		207	5 0
Allow half the above for extra widths in high banking and deep cutting, passing places,			
turning places, docks, basons, cranes, engines, temporary damages, and spoil of			
ground,		103	12 6
To six small tunnels at £10. each, and two larger ditto, at £20. each, making in the			
whole eight subterraneous passages, per mile,		100	0 0
To one road bridge per mile at £60., and two more for communication between the			
lands severed, at £30. each, making three passages over the canal, per mile,		120	0 0
To making towing-paths, back drains, fences, gates, &c. at two shillings and sixpence			
per yard running,		220	0 0
Neat estimate per mile,		1115	17 6

ESTIMATE of the works of Schedule No. 1, applicable to the whole length of the canal.

	£	s.	d.
To ninety-one miles of canal, at £1115 17s. 6d. per mile,	101,544	12	6
To five engines for lifting and lowering the cargoes from the level of one canal to another, which, supposing the incidental expense of sinking shafts, and making tunnels, cannot be stated at less than £1000. each,	5000	0	0
To building a dam, or other equivalent work, across the Bude river, for communicating the canal across the valley and river,	100	0	0
To three principal aqueducts, tunnels for crossing the rivers Attry, Kenzie, and Inny, at £100. each,	300	0	0
To making six overfalls for discharging the waste water in time of great rains, at £40. each,	240	0	0
To six sluices for emptying the several stretches of canal, in order to clean, &c. at £30.	180	0	0
To six small shuttles and aqueducts for taking in water from the rivulets, at £10. each,	60	0	0
To six stop-gates for preventing the whole of the water from flowing off in the long reaches, in case of accident, or occasion for a partial cleansing and repair,	120	0	0
To cutting an aqueduct from Shernock moor weir to the canal of partition near the Pack-saddle, being in length four miles, supposed a five feet bottom, three feet deep, and slopes as one to one, this will contain $14\frac{2}{3}$ cube yards per rod, say 15, which, at $1\frac{1}{2}$ d. per yard, will be £30. per mile, and for four miles,	120	0	0
Allow half of this for extra cutting and banking,	60	0	0
The ground occupied by the aqueduct and banks will be half a chain broad, which, in four miles, will contain sixteen acres, which, if valued at the average price of £22 10s. will come to	360	0	0
To a new weir at Shernock moor, and stop-gates for taking water into the aqueduct,	80	0	0
In dry seasons the navigation will be likely to take all the water of the Tamar into the Shernock aqueduct, and thereby deprive the mills of Bridge Rule and Langerton thereof; if we suppose the average damage done to each at £5. per annum, this, at twenty years purchase, will make a capital of	200	0	0
Neat estimate,	108,364	12	6
Allow for contingencies, and unforeseen expenses upon the above, at £10. per cent.	10,836	9	3
	119,201	1	9

ESTIMATE

ESTIMATE of the expence of freight in bringing twenty tons of sand from Bude Haven to Launceston by the said canal, being in length forty-nine miles by its course.

	£	s.	d.
To filling the sand into carts or boats in the haven, and carrying it to the foot of the first engine, at $1\frac{1}{2}d.$ per ton, - - - - -	0	2	6
To delivering the sand into the buckets, hoisting the same, and loading and trimming the boat in the canal above, at $1\frac{1}{2}d.$ per ton, - - - - -	0	2	6
Trackage upon the canal from the first and second engine, at three-pence per mile loaded going, and returning light, at two-pence, that is, five-pence per mile, upon a length of $6\frac{1}{2}$ miles, by the course of the canal, - - - - -	0	2	$8\frac{1}{2}$
A trip will easily be made in this reach per day, allowing for stoppages, the boatman at one shilling and sixpence, and the boat or boats to carry twenty tons, at three shillings, together per day four shillings and sixpence, - - - - -	0	4	6
Expense of first reach, - - - - -	0	12	$2\frac{1}{2}$
In the second reach, changing the cargo, as in the former, at $1\frac{1}{2}d.$ per ton, - - - - -	0	2	6
Trackage in this reach, four miles, at five-pence, - - - - -	0	1	8
Two trips may be made in this reach per day, therefore, the man and boat hire will be half a day, at four shillings and sixpence, - - - - -	0	2	3
Expense of second reach, - - - - -	0	6	5
In the third reach, changing the cargo, - - - - -	0	2	6
Trackage, $38\frac{1}{2}$ miles, at five-pence, - - - - -	0	16	$0\frac{1}{2}$
In this reach it will take three days to make a trip backwards and forwards, reckoning twelve hours to the day, at four shillings and sixpence, - - - - -	0	13	6
Expense of third reach, - - - - -	1	12	$0\frac{1}{2}$
Ditto, of second reach, - - - - -	0	6	5
Ditto, first reach, - - - - -	0	12	$2\frac{1}{2}$
Total expence of twenty tons from Bude to Launceston, - - - - -	2	10	8
The land-carriage from Bude to Launceston being stated by Mr. Leach at three pounds per eight tons, this, for twenty tons, will cost - - - - -	7	10	0
Saved upon one cargo, - - - - -	4	10	4
And if upon this saving we allow half to the consumer for land-carriage from the canal to his situation, and the other half to pay the interest of the capital, there will be for each purpose, - - - - -	2	9	8

Mr.

Mr. Leach supposes that 8960 acres of land will be manured yearly within the reach of the canal by sand and lime jointly; and supposing one half, that is, 4480 acres, be manured with sand, and the other with lime, then, as he states it, that ten tons of sand is at an average laid upon $1\frac{1}{2}$ acre, there will be wanted for 4480 acres, 33,600 tons annually, amounting to 1680 cargoes of sand annually of twenty tons each.

But 1680 cargoes, upon a profit of £2 9s. 8d. per cargo, amounts to the annual sum of £4172.

Again.—It is said, that 100 bushels of lime, weight $3\frac{1}{2}$ tons, does an acre of land at an average; therefore, 4480 acres will require 14,933 tons, equal to $746\frac{2}{3}$, say 747 cargoes of twenty tons each, the land-carriage of which to Launceston is stated at £1 16s. per 100 bushels, that is, per cargo, £10 16s. Now, if the neat expense of freight is stated to Launceston at the same rate as from Bude, viz. £2 10s. 8d., which, though the distance is less, it reasonably may, on account of greater risk in carrying lime than sand, then:

	£	s.	d.
The land-carriage being	-	10	16 0
The water carriage,	-	2	10 8
There will be a saving per cargo,	-	8	5 0

And if this be also equally divided between the consumer for land carriage, and greater waste and loss in the commodity, and the other half to the proprietors for payment of interest, there will be a profit, per cargo, of

	4	2	8
And this upon 747 cargoes will amount to per annum	3087	12	0
The profit upon sand, as before stated,	4172	0	0
Total	7259	12	0

Now, if £7259 12s. will pay the interest of a capital of	145,192	0	0
And the estimated capital be	119,201	1	9
The capital maintained will exceed the capital to be raised,	25,990	18	3

that is, the estimated capital is to the exceeding, as one hundred to twenty-two, nearly.

SCHEDULE,

SCHEDULE, No. 2.

State of the case on supposition of the execution of Mr. Call's proposition of carrying the canal by Greena Moor, by which the course of the canal from Bude Haven to Launceston will be shortened fifteen miles.

	£	s.	d.
Saved by fifteen miles of canal, at £1115 17s. 6d. per mile,	16,738	2	6
Ditto, by omission of the Shernwick moor aqueduct,	620	0	0
And by damages to Bridge Rule and Langerton mills,	200	0	0
	17,558	2	6
But as by this scheme two more engines or lifts will be wanted, or what will amount to an equivalent expense, from this must be deducted	2000	0	0
Neat savings,	15,558	2	6
Neat estimate per schedule, No. 1.	108,364	12	6
Neat expense per Mr. Call's plan,	92,806	10	0
To which add ten per cent. contingencies, as before	9,280	13	0
The estimated capital,	102,087	3	0

ESTIMATE of the expense and freight in bringing twenty tons of sand from Bude Haven to Launceston, by the canal so shortened, being in length thirty-four miles.

	£	s.	d.
Expense of the first reach, as before, 6½ miles,	0	12	2½
Ditto, second, as before 4	0	6	5
Ditto, third and fourth, supposed together, 8 as per last,	0	12	10
In the fifth reach, changing the cargo,	0	2	6
Trackage, 15½ miles, at five-pence,	0	6	5½
A trip made in two days, man and boat, four shillings and sixpence,	0	9	0
Neat expense of the freight of a cargo,	2	9	5
Land carriage from Bude to Launceston, as before,	7	10	0
Saved upon one cargo,	5	0	7
This being divided equally between the consumer and proprietors will leave to pay interest per cargo,	2	10	3½

Now,

Now, 1680 cargoes of sand, at £2 10s. 3½d. amount to per annum,	-	-	£	s.	d.
And 747 cargoes of lime, as before, at £4 2s. 8d. amount to	-	-			
			4,224	10	0
			3,087	12	0

Total per annum, - - - 7,312 2 0

But £7312 2s. will pay the interest of	-	-	-	146,971	4	0
The estimated capital,	-	-	-	102,087	3	0

The capital maintained will exceed the capital raised, - - - 44,884 1 0

that is, the estimated capital will be to the exceeding as one hundred to forty-four.

SCHEDULE, No. 3.

State of the case upon supposition of executing the northern part of the canal, that is, from Bude Haven to Launceston, upon Mr. Leach's plan.

ESTIMATE of the expense.

			£	s.	d.
To forty-nine miles of canal, at £1115 17s. 6d. per mile,	-	-	54,677	17	6
To three engines for three lifts, at £1000. each,	-	-	3,000	0	0
To building a dam across Bude river, as before,	-	-	100	0	0
To two large aqueduct tunnels for crossing the Attry and Kenzie waters, at £100. each,	-	-	200	0	0
To five over-falls, sluices, stop-gates, and shuttles for taking in water,	-	-	500	0	0
To Shernick moor aqueduct, and damage to bridge rule and Langeston mills,	-	-	820	0	0
Neat estimate,	-	-	59,297	7	6
Add ten per cent. contingencies, as before,	-	-	5,929	15	9
Estimated capital,	-	-	65,227	13	3

Now it is supposed, that in this case, the carriage of lime will be lost, but the quantity of sand before specified in schedule, No. 1, will be carried from Bude to Launceston, viz. 1680 cargoes, leaving a profit of £2 9s. 8d. per cargo, amounting to, per annum,

	-	-	-	4,172	0	0
But £4172. will pay the interest of	-	-	-	83,440	0	0
The estimated capital,	-	-	-	65,227	13	3

The capital maintained will exceed the capital raised, - - - 18,212 6 9

that is, the estimated capital will be to the exceeding as one hundred to twenty-eight.

Consequently, the executing of the north end of the canal upon Mr. Leach's plan from Bude to Launceston, will be a better adventure than executing the whole, and therefore much better than executing the south part from Launceston to Calstock only.

SCHEDULE, No. 4.

State of the case on supposition of executing the northern part of the canal from Bude Haven to Launceston, upon Mr. Call's plan.

ESTIMATE of the expense.

	£	s.	d.
To thirty-four miles of canal, at £1115 17s. 6d. per mile,	37,939	15	0
To five engines, at £1000. each,	5,000	0	0
To dams, aqueducts, over-falls, and sluices, as per estimate, No. 3.	800	0	0
Neat estimate,	43,739	15	0
Add ten per cent. contingencies, as before,	4,473	19	6
Estimated capital,	48,113	14	6
Here again it must be supposed that the carriage of lime will be lost, but that the 1680 cargoes of sand will remain to be carried from Bude to Launceston, as specified schedule, No. 1, but which leaving a profit of £2 10s. 3½d. per cargo, as per schedule, No. 2, this will yield per annum,	4,224	10	0
But £4224 10s. will support a capital of	84,490	0	0
The estimated capital,	48,113	14	6
The capital maintained will exceed the capital raised	36,376	5	6

that is, the estimated capital will be to the exceeding as one hundred to seventy-six.

Hence it appears also, that not only the execution of the north part of the canal will be more advantageous than the whole, but that the shortening of the length will be a great advantage also.

SCHEDULE,

SCHEDULE, No. 5.

Scheme for executing a canal partly by locks, and partly by engines, to go up the valley of the Bude river by locks from the Haven to the proposed engine at Longford hill, from thence across the Pack-saddle by canals and engines, as per Mr. Leach's plan, and then to fall down by an engine into the valley of the Tamar, and down that valley by locks and canals to Greston bridge.

IT is necessary to premise, that the cutting a canal in the easy declining vallies of rivers, being a matter of different consideration from that of cutting canals upon the sloping and winding sides of hills; to the latter of which the estimate for a mile of canal in Schedule, No. 1, is accommodated; a particular estimate has been made upon the same dimensions for the former; and that the advantages and disadvantages so nearly compensate one another, that as the difference turned out but a few shillings per mile, the same price is taken in the following, as in the former estimates, that uniformity may be preserved.

ESTIMATE of the expense.

	£	s.	d.
To 3½ miles from Bude Haven to Longford hill, at £1115 7s. 6d.	3,905	11	3
To six locks, at £600. per lock,	3,600	0	0
To an engine at Longford hill, according to Mr. Leach's plan,	1,000	0	0
To four miles of canal to the next engine, at £1115 7s. 6d. per mile,	4,463	10	0
To an engine for lifting the goods to the canal of partition, crossing the Pack-saddle,	1,000	0	0
To two miles of canal from the second engine across the Pack-saddle beyond Thorn,			
where a third engine is to be placed,	2,231	15	0
To the third engine to transfer the cargoes to the level of the Tamar's valley,	1,000	0	0
To 15½ miles of canal from that engine to Greston bridge,	17,295	1	3
To ten locks, at £600. each,	6,000	0	0
To two capital aqueduct bridges for crossing the Attry and Kenzie rivers, at £300. each,	600	0	0
To the Shernick moor aqueduct, and damage to Bridge Rule and Langeston mills,	820	0	0
Neat estimate,	41,916	17	6
Add ten per cent. contingencies as the former,	4,191	13	9
Estimated capital,	46,108	11	3

ESTIMATE

ESTIMATE of the expence of the freight of twenty tons of sand.

	£	s.	d.
Bringing the sand to the beginning of the canal, and lading the same on board the vessels, taking it as much as bringing and hoisting by the first machine, as before stated, at three-pence per ton,	0	5	0
Trackage from Bude Haven to Longford hill, $3\frac{1}{2}$ miles, at three-pence,	0	1	$5\frac{1}{2}$
This distance will allow two trips per day, therefore man and boats,	0	2	3
First district from Bude to Longford,	0	8	$8\frac{1}{2}$
The second reach as per schedule, No. 1,	0	6	5
In the third reach, or canal of partition, changing the cargo into the same,	0	2	6
Trackage of the canal of partition, two miles, at five-pence,	0	0	10
Changing the cargo at the third machine, down to the valley of Tamar,	0	2	6
In this reach three trips may be made per day, which, at four shillings and sixpence boat and man,	0	1	6
Third reach, being in the canal of partition,	0	7	4
In the district of canal from the third machine to Greston bridge, being about $15\frac{1}{2}$ miles, at five-pence,	0	6	$5\frac{1}{2}$
This will take two days to a trip, therefore boat and man, at four shillings and sixpence,	0	9	0
Expense of the fourth stretch, from the third machine to Greston bridge,	0	15	$5\frac{1}{2}$
Canal of partition, or third reach,	0	7	4
The second reach,	0	6	5
The first stretch,	0	8	$8\frac{1}{2}$
Total expense of freight,	1	17	11
Suppose the sand at Greston bridge worth no more than at Launceston, viz. as before,	7	10	0
Saved per cargo,	5	12	1
And suppose this divided as before between the consumer and proprietors, there will be to each,	2	16	$0\frac{1}{2}$
Suppose also the number of cargoes to Greston bridge no greater than if stopped at Launceston, that is, 1680 cargoes, at £2 16s. $0\frac{1}{2}$ d.	4707	10	0
	But		

KINGSTON AND EWELL CANAL.

The REPORT of JOHN SMEATON, engineer, concerning the effect that the execution of a canal from the river Thames at or near Kingston to Ewell, in the county of Surry, will have upon the several mills worked by the stream in its course.

FOR effecting a navigable canal through this valley, two schemes have been submitted to my consideration, one of them drawn up by Messrs. Nichols and Broughton, which, in general, keeps the flat ground in the bottom of the valley, the other by Mr. Whitworth, who, in general, keeps the rising grounds in preference to those of the valley; and having viewed the two different lines proposed, and considered in what manner each of them is circumstanced, that we may see how the mills will be affected by the execution of either plan, it is in the first place necessary to ascertain the quantity of current water in the river Ewell, particularly at those times of the year, when the mills are capable of using it all. The time of my view was in the middle of August last, and from my observations then taken, it appears that the river Ewell afforded, according to my calculation, at or about 700 cube feet of water per minute, that is, at the rate of 4987, or nearly upon 5000 hogheads per hour; but I was informed, that though this was a very dry season, yet the river depending almost wholly upon springs, it was not the time of the shortest water, and judging by the average difference of effects reported respecting the working of the mills in those short-water times, I conclude, that at those times the river does afford full 500 cube feet per minute, or 3562 hogheads per hour; for though at some very particular times there is still less, yet these happening but seldom, I lay them out of the account.

To determine what part of the water ascertained as above will be needed for the navigation, it is necessary to know the cost that will attend the execution of either plan; that from judging from the quantity of business which must be done to support that capital, we shall be enabled to ascertain what water must be taken to do that business, and that both these plans may be put upon the same grounds, I have made an estimate of the probable expense likely to attend each, in such a way as I should myself direct the execution, both of which I have hereto subjoined.

The probable expense of Mr. Whitworth's line, so estimated, amounts to the sum of £20,436, which is for the performance of the works and purchase of lands, exclusive

clusive of all expenses preceding the application, and in procuring an act of parliament, as well as interest of money, committees, meetings, and law charges, during the procedure of the works. Therefore, to answer not only those contingencies, but the repairs of the navigation after it is opened, the salaries of lock-keepers, clerks, and other necessary agents to be employed therein, it appears to me necessary, that the gross tolls which may be expected to arise therefrom, should be equivalent to the interest of five per cent. of a sum half as large again as the estimated sum, and calling it £20,000, there will be needed tolls to the amount of the interest of £30,000, which is £1500 per annum.

Mr. Whitworth states, that a chaldron of coals is carried from Kingston to Ewell by land-carriage for six shillings, but to give a preference to the water-carriage, and to extend the present sphere of business, this ought to be done for four shillings, which must include freight and tolls.

Now the freight and incidental charges of loading and unloading must be first paid, whether more or less remains for the tolls; I have therefore particularly considered the article of freight, in the sort of vessel that seems best accommodated to such a trade, that is, such a vessel as will not only navigate this canal, but take up from, and carry her cargo to London, a vessel of thirteen feet breadth, fifty feet in the tread of the keel, and drawing loaded about three feet four inches water, will carry thirty-six tons neat weight, which, according to my computation, will be rather better than, but say, twenty-five chaldron of coals. And though I would suppose, when bargemen are brought to work one against another, it will be done for considerably less, yet in a case of this kind, I cannot compute upon a less freight and incidental charges from Kingston to Ewell than twenty shillings upon a cargo of twenty-five chaldrons; but twenty-five chaldrons of coals, at four shillings, is five pounds, so that there will remain four pounds per cargo that may be taken for tolls, that is, at the rate of 3s. 2 $\frac{1}{3}$ d. per chaldron.

Again, I suppose, that though coals may be the principal article with which barges will go up with full loads, yet of corn, timber, and the produce of the mills, I would suppose them at an average to carry half loads down, that is, eighteen tons of goods, which, if paying the same tonnage as coals, will pay downwards half as much as up, that is to say, forty shillings, which will be 2s. 2 $\frac{2}{3}$ d. per ton, tolls, and with freight at the same rate as coals, amounting to 6 $\frac{2}{3}$ d, in the whole, will amount to

will amount to 2s. 9 $\frac{1}{2}$ d. which will be at the rate of 6 $\frac{2}{3}$ d. per quarter upon corn, freight and tolls, to the Thames at Kingston.

A barge paying therefore a toll at an average of £4 up, and £2 down, will pay per trip £6. But £1500, the annual sum to be produced, divided by £6, will make 250 trips of such vessel per annum; to quit the outlay and pay the interest.

Now 250 trips requiring a lock-full up, and another down, there will be annually consumed 500 locks-full, for in the simple case of navigable locks, supposing them all of the same rise, what will work one will work all the rest; these 500 locks-full, averaged upon 365 days, will be as follows:

	Cube feet;
Lockage per day - - - - -	8,968
Leakage of locks (supposed two locks-full per day) - - - - -	12,194
Evaporation from the surface of the canal - - - - -	6,314
Soakage into the ground, allow the same - - - - -	6,314
Water expended per day by the navigation - - - - -	33,790

Now seven times this quantity, viz. 236,530 cube feet, will be the average consumption for a week, whereas the river in its lowest state affording 500 cube feet per minute, will supply in one day 720,000 cube feet, that is, the river in its lowest state supplies above three times as much water in one day, as the navigation will consume in a week; if therefore the mills are supposed to lie still on Sundays, and the Sundays' water be turned into the canal, this will be much more than sufficient for its supply for a week, and upon this construction of a canal I have made my estimate; the lockage and leakage out of the reservoir or pond of the first mill excepted, which amounts to no more than one thirty-fourth part of the river's water in short-water times, and about one forty-eighth part only of the water in summer, such as I found it, which would be recompensed by five pence a trip upon each barge, amounting to £5 4s. 2d. say £5 5 per year, as I shall shew more particularly hereafter, if occasion shall require.

My estimate upon the same prices and co-incident proportions, for the line of Messrs. Nichol and Broughton, amounts to £18,029, calling this £18,000, the sum for which the tolls must pay interest will be £27,000; the interest of which, at five per cent. will be £1350, so that, supposing the number of cargoes to be the same,

as

as by the former, and the tolls the same also, then here will be an exceeding of tolls, above the estimated out-goings and interest, of £150 per annum, to make good further contingencies; or it will allow the tolls upon a chaldron of coals to be lowered five-pence, so that they will then be, tolls and freight, three shillings and seven-pence per chaldron, instead of six shillings land carriage, and this will occasion a proportionable extension of trade and consumption; or otherwise, if the tolls are kept at the same price, the annual amount thereof will be raised by five cargoes less.

But whatever may be thought proper as to prices, it is certain that this will occasion a less consumption of water; for the canal being dug in the bottom of the valley, will be more likely to raise springs, than take in water by soakage, and therefore that article, amounting to 6314 cube feet per day, which is, in fact, the most uncertain of the whole, may be laid out of the account.

In case the navigation is brought only to the tail of the paper mill, as has been suggested, there will be saved nearly upon either scheme as follows:

	£	s.	d.
In making the wharf, about	200	0	0
In digging	133	3	8
In land	225	0	0
By twenty feet of lockage, at £80	1600	0	0
By two over-falls and tunnels	40	0	0
By one quarter a mile of towing-path, &c.	55	0	0
Neat estimate	2253	3	8
By ten per cent. contingencies upon the above	225	6	4
To be deducted	2478	10	0

which, deducted from the estimate of Mr. Whitmore's line, leaves 17,758 7 8
and, deducted from the estimate of Messrs. Nichol and Broughton, leaves 15,550 12 4

But then a road to the wharf must be considered.

It has been suggested that the navigation may be supplied by the Sunday's water, the uppermost lock excepted, and, if this mode be adopted, it will behove the proprietors of mills to have a clause inserted in the act, to prevent any water from being unnecessarily drawn; and for this purpose it will be proper, that a couple of men be employed to attend the boats up and down through the locks to see that no water be mis-spent; their wages to be paid by the navigation company, but their appointment and dismissal to

depend upon the occupiers of mills for the time being. It appears practicable, therefore, in nature, to supply the navigation without loss to the mills; but, as every human purpose is capable of being defeated, let us see what damage the mills can suffer, in case of a different application.

If the lockage only be taken constantly from the river, which indeed would be convenient, it will deprive the mills of one ninety-fifth part only of their water in the ordinary summer's drought, and not more than one sixty-ninth part thereof in the short-water season, which loss may very well be compensated by the clauses common in this kind of acts; the millers being allowed to bring up mill-stones, timber, and materials for the re-building and repairs of their mills, toll-free. But if the whole expenditure of water, viz. 33,790 cube feet be immediately to be taken from the river at all times promiscuously as wanted, it will take one-thirtieth part of the water in common summer seasons, and one twenty-first part of the water in short-water times, which, though capable of a recompense, yet as even then it would be necessary to keep a couple of men to attend the passage of the vessels through the locks, to see that a much greater misapplication of water by negligence of bargemen, &c. than has been calculated did not ensue; the evil may be almost as easily prevented in the whole, (except as to lockage only), as in part.

It appears to me, therefore, upon a full view of the matter, that under the proper restrictions, it will be the interest of the proprietors of mills to encourage this scheme of a navigable canal, on supposition that each scheme is equally eligible to the land-owners, the keeping the low grounds not in the exact line pointed out by Messrs. Nichols and Broughton, but somewhat near the same, will be more eligible to the proprietors of mills, not only as coming nearer to them, but by being liable to less risk and misapplication, as being attended with no soakage water.

The great general question, therefore, is reduced to this, respecting the eligibility of a navigation, that since 250 trips, or somewhat toward the same, appear to be requisite to support the capital necessary to make it, whether the consumption of the country will be likely to require 6000 chaldrons of coals, or their equivalent in other goods, to go up the river annually, at four shillings per chaldron, freight and tolls, and 22,000 quarters of corn at 6½d., freight and tolls, to go down, or their equivalent weight in timber, or other commodities, to the amount of 4500 tons? This can only be judged of by those well acquainted with the extent of country most likely to be supplied from, or bring commodities to Ewell, to whom I must refer this point. It being evident that a less quantity

quantity upon the whole will not quit the cost ; but if a much greater is supposed, then the tolls can be laid lower.

J. SMEATON.

Austhorpe, 29th Jan. 1778.

N. B. In the above calculations, I supposed that for one-half of the year, the waste water of the river, more than what supplies the mills, will work the navigation, in ordinary course, without any particular attention to the loss of water ; that one quarter more the river is affording at the average rate of 700 cube feet per minute, in ordinary drougths in summer, and that the other quarter may be called the short-water season, when the river is supposed to afford 500 cube feet per minute. It appears also to me, that in the two last-mentioned states, the quantity of water will be nearly the same at Kingston as at Ewell, having remarked no branch of supply of any consideration, and that the small springs taken in during this course, nearly balance the evaporation. As, therefore, in all probability the barges will not need attending above half the year, and in the whole year there being only 250 trips, this will not be at the average of a trip per day. Two men will, therefore, easily attend, one to each barge, both up and down, but I do not propose to fix it to two men ; but that, in proportion to the trade, every barge shall be attended by a man both up and down, and indeed this will, in fact, be much for the company's interest, as the best means of preventing damage by the misuse of their works.

The great exceeding of my estimate, upon the line of Messrs. Nichols and Broughton, above their own, will, doubtless, attract attention, wherein it is to be noted, that they have not taken the purchase of lands into their estimate, and the digging seems not to be valued at above $2\frac{1}{2}d.$ per yard. No allowance for hauling tracts, &c. or wharf at the head.

J. S.

ESTIMATE for the Ewell canal, upon the line of Mr. Whitworth.

	£	s.	d.
The bottom being sixteen feet, slopes three to five, five feet deep, will contain 23,793 cube yards per mile, which, at four-pence, will come to £396 11s. per mile, and for five miles one furlong to		2,032	6 4 $\frac{1}{2}$
Allow for banking up and extra cutting through uneven grounds, hard matter, puddling, sandy, and channelly grounds, making passing places, &c. one-third of the above,		677	8 9 $\frac{1}{2}$
Carried forward		2,709	15 2
		According	

	£ s. d.
Brought over	2,709 15 2
According to the above dimensions, the ground wanted in the plain cutting will be one and a half chain broad, that is, twelve acres per mile, which, if valued at the average price of £60. an acre, as supposed by Mr. Whitworth, will come to £720. per mile, and for $5\frac{1}{8}$ miles to	3,690 0 9
Allow for extra widths in high banking and deep cutting, passing places, turning places, landing places, temporary damages, and spoil of ground, one quarter of the above,	922 0 0
To lockage, eighty-six feet, at £80.	6,880 0 0
To making an over-fall and tunnel at each lock, supposed No. 12, at £20. each,	240 0 0
To three turnpike road bridges, at £150. each,	450 0 0
To seven smaller road bridges, at £90. each,	630 0 0
To five communication bridges between lands, to make in the whole at the average of three passages per mile, at £50.,	250 0 0
To making a wharf at the head, as per Mr. Whitworth,	420 0 0
To making an aqueduct over the river below the paper mill, with banking,	200 0 0
To ditto, near Malden powder mills, with ditto,	300 0 0
To extra cutting and impediments, between No. 63, and No. 67, inclusive,	252 8 2
To extra charge in the Thames lock, lock pit, drainage, foundation, and building,	250 0 0
To making small tunnels, supposed at the average of one per mile, that is, No. 5, at £15.,	75 0 0
To making towing-paths, back-drains, fences, gates, stiles, &c. at two shillings and six pence per yard running, that is, per mile, £220., and for $5\frac{1}{8}$ miles,	1,127 10 0
Neat estimate,	18,397 3 4
Add ten per cent. contingencies upon the above, exclusive of all expenses preceding the application, and procuring an act of parliament, as also interest of money, and law charges, &c. during the procedure of the work,	1,839 14 4
Total estimate for works and land,	20,336 17 8

ESTIMATE for the Ewell canal, upon the line of Messrs. Nichols and Broughton.

	£ s. d.
The bottom being sixteen feet, slopes three to five, and five feet deep, will contain 23,793 cube yards per mile, which, at four-pence per yard, will come to £396 11s. per mile, and for five miles one furlong,	2,032 6 $4\frac{1}{2}$
Allow for banking up and extra cutting through uneven grounds, hard matter, making passing places, &c. one-eighth of the above,	254 0 9
Carried forward	2,286 7 $1\frac{1}{2}$
Brought	

	£	s.	d.
Brought over	2,286	7	1½
According to the above dimensions, the ground wanted in the plain cutting will be one and a half chain broad, as the other, that is, twelve acres per mile, which, if valued at the average price of £60. per acre, as before, will come to £720. per mile, and for 5½ miles, to	3,690	0	0
Allow for extra widths in high banking and deep cutting, passing places, turning places, landing places, temporary damages, and spoil of ground, one-eighth of the above,	461	5	0
To lockage, eighty-six feet, at £80.,	6,880	0	0
To making an over-fall and tunnel to each lock, supposed No. 12, at £20.,	240	0	0
To one turnpike road bridge, and altering Clatton bridge, at £150. each,	300	0	0
To two road bridges of a lesser kind, at £120. each,	240	0	0
To three small road bridges, at £90. each,	270	0	0
To five communication bridges between lands, at £50. each,	250	0	0
To making a wharf at the head, as before,	420	0	0
To expenses in crossing the river, supposed three times,	150	0	0
To making small tunnels, supposed at an average one per mile, at £15.,	75	0	0
To making towing-paths, back-drains, fences, gates, stiles, &c. at two shillings and sixpence per yard running, that is, £220. per mile, for 5½ miles	1,127	10	0
Neat estimate,	16,390	2	1½
Add ten per cent. contingencies upon the above, exclusive of all expenses preceding and procuring an act of parliament, as also interest of money, and law charges, &c. during the procedure of the work,	1,639	0	2½
Total estimate for works and land,	18,029	2	4

J. SMEATON.

Austhorpe, 27th January, 1778.

RIVER TYNE CANAL.

The REPORT of JOHN SMEATON, engineer, upon the practicability and probable expense likely to attend the extension of the navigation of the river Tyne, by a canal on the south side of the river, from Stella, by Ryton, towards the grounds opposite Wylam.

HAVING taken a view of the ground through which a canal was proposed to be carried, by Captain Bainbridge, and in company with him who pointed out the same, the scheme appears to me very feasible, without any natural impediment, save that the natural banks lie steep upon the river in passing by Ryton; nevertheless, by an extra expense, which will appear no ways formidable in proportion to the whole, this difficulty may be overcome. This report being founded upon a mere view, without having either measures or levels, which must, nevertheless, be supposed, in order to bring the matter to a calculation, the estimate cannot be thought to be very correct, but yet may serve, by giving an idea of the probable expense that is likely to be incurred, to shew whether the scheme is likely to bear; because, if it will bear an expense of £6000 or upwards, exclusive of the cost of procuring an act of parliament, and of all plans and surveys, with other charges, previous and preparatory thereto, as well as clear of interest of money advanced during the performance, then it will be adviseable that an accurate plan and level be taken, from which an estimate may be made that will be likely to come as near the matter as the nature of this kind of subjects can possibly admit; but as this cannot be done without time and accuracy, and, in consequence, at a considerable expense, that will be avoided by this previous estimate, in case the subject is not likely to bear the expense thus ascertained.

The following is an estimate for a canal of the smallest dimensions I can possibly recommend to be executed, yet it will carry vessels of twelve feet wide, and drawing $2\frac{1}{2}$ feet water, which, at forty-two feet in the tread of the keel, lighter built, will carry twenty-one tons neat weight, that is, nearly eight chaldrons, Newcastle measure: vessels of this kind would, doubtless, be able to carry coals down to the harbour of Shields, in moderate weather, so far as regards the performance of the navigation, but how far they might answer in point of strength, I cannot properly judge, but apprehend the keels are built of such bulk and strength as they are, not only on account of security of navigation in bad weather, but to resist the blows they receive against the sides of the ships, as I apprehend they are often liable to be squeezed between them; on this account they are very particularly guarded in point of strength, by the breadth of their gunwales.

I am

I am not very certain of the length of canal computed upon, not having had a good opportunity of consulting the best county map, but if the length be greater or less than three miles, as I have supposed it, the cost of the work estimated by the mile, will be in proportion to the length, and the other charges thereon will remain the same.

Austhorpe, 26th Feb. 1778.

J. SMEATON.

ESTIMATE for making three miles of canal from Stella, by Ryton, towards the grounds opposite Wylam, on the south side of the river Tyne.

	£	s.	d.
To be three feet deep of water, twelve feet wide at bottom, with sufficient slopes on each side.			
The ordinary digging per mile,	283	17	9
Purchase of lands, at £40 per acre	460	10	0
The chance of bridges, tunnels, towing-paths, back drains, fencing, &c. in that situation	430	0	0
Neat estimate per mile	1174	7	9
To three miles of canal, at £1174. 7s. 9d. per mile	3523	3	3
To three locks, estimated at	1910	0	0
To probable expenses attending the taking in water	100	0	0
The extra expense likely to attend the passing of the steep banks at Ryton, supposing the length one quarter of a mile	176	0	0
Neat estimate	5709	3	3
Allow for contingent expenses, temporary damages upon the above, at the rate of ten per cent.	570	18	4
	6280	1	7

Austhorpe, 26th Feb. 1778.

J. SMEATON.

KANQUARRY

KANQUARRY CANAL.

The REPORT of JOHN SMEATON, engineer, upon the practicability and utility of making a navigable canal from Kanquarry to or near the new bridge over the river Plym, in the county of Devon.

HAVING, in the month of September last, by the desire of John Parker, esq. taken a view of the tract of ground between the valuable slate quarry, called Kanquarry and new bridge, to which place the tide reaches, and admits of barges to go up from Plymouth, there is no doubt of the practicability of the proposition, both respecting the situation of the ground and a supply of water, nor is there any doubt but that by a canal so effected, the produce of this quarry might be brought down much cheaper than by the present mode of land carriage; the principal or previous question then is, whether the business that is likely to be done upon this canal, be likely to quit the outlay upon it. For this purpose I have carefully computed the probable expense, without particularly entering into the mode of it, that must naturally attend such a scheme, and to make a canal of twelve feet bottom, with suitable locks to carry down the vessels into the tide's way, the length being about $2\frac{1}{4}$ miles, and the perpendicular descent, about thirty feet, will cost the estimated sum of £2476, which we may call £2500.

The land carriage I estimate at sixpence per ton per mile, therefore, for $2\frac{1}{4}$ miles, the expense will be $13\frac{1}{2}d.$ per ton.

The freight of the slates per ton, by water, including loading and unloading, I compute at $6\frac{1}{4}d.$ per ton, the savings therefore on land carriage, supposing the navigation could be made and upheld for nothing, would be $7\frac{1}{4}d.$ per ton.

The interest of £2500, at five per cent. per annum, is £125, but I estimate that to keep all in repair, and support the principal for ever; the navigation, besides paying the above sum at interest, ought to raise sixty-five pounds per annum more, in the whole £190 per annum; to raise which sum upon a profit of $7\frac{1}{4}d.$ per ton, there must be navigated 6290 tons annually, all carried more than this will yield a profit of $7\frac{1}{4}d.$ per ton, and all less will be a loss to the proprietor of $7\frac{1}{4}d.$ for every ton deficient of the above quantity.

Apprehending

Apprehending the above tonnage of slates to be considerably greater than is, or is likely to be vended from the said quarry, I have turned my thoughts to what may be done by means of a rail road, such as is used in coal countries for the land-carriage of coals to the navigable rivers, &c. and I find that to construct a waggon rail-road, proper for this service, would cost the estimated sum of £1089, which we may fairly call £1100, the interest whereof, at five per cent. per annum, is fifty-five pounds, but to keep this in perpetual repair in like manner as the navigation, it ought to raise fifty-five pounds more, that is £110 per annum.

I compute further, that the expense of loading down the slates by this road, will cost, loading and unloading included, seven-pence per ton, which, deducted from $13\frac{1}{2}d.$ supposed the present land-carriage, leaves $6\frac{1}{2}d.$ per ton to raise £110 per annum, which will require an out-put of 4060 tons; all over will, in like manner as in the navigation, be a profit of $6\frac{1}{2}d.$ per ton, and all under so much annual loss.

It is further to be observed, that in case the present land-carriage of a ton of slates amounts to more than $13\frac{1}{2}d.$ then the difference will be in favour of either scheme; because the difference between the estimated price, and that of the present land-carriage being greater, an out-put of a smaller number of tons will compensate the out-lay, and the profit be sooner arrived at.

I have mentioned that a canal of a twelve-feet bottom is as small as in my opinion can be executed with advantage; I do not mean that a smaller canal may not be made for less money, but as the extra bankings, cuttings, bridges, and locks, will be nearly the same, and nothing saved but in the plain cutting in the middle of the canal, when this compared with the want of freedom, and facility of passage, or the necessity of using smaller boats, the freights being thereby increased, more than the proportion of the out-lay is diminished, the probability of profit upon the whole will be less.

Nor can engines for lowering the materials be used to advantage in lieu of locks, in this situation, unless the barges could be brought under the engines, so that the materials could be lowered into the very vessel, (which, indeed, is very practicable), but the addition of expense incurred hereby, would be as great or greater than could be saved from the construction of locks, which are certainly the most commodious mode of navigating yet found out.

J. SMEATON.

Austhorpe, 15th May, 1778.

KNOTTINGLEY LOCK.

The REPORT of JOHN SMEATON, engineer, upon the situation proper to be adopted for a new lock at Knottingley.

THE making of a new cut through the marsh is doubtless the most eligible mode of doing the business, but as I understand that this is attended with difficulties scarcely to be surmounted, then it appears to me that the most eligible scheme, and which, when finished, will nearly amount to the same thing, will be to form the cut by artificial means within the trough of the river, by placing the lock lower down upon the peninsula, something near the place proposed by Mr. Jessop; for in regard to the rebuilding the lock in the present situation, the going into it, and out of it, at the tail below, is so extremely crooked, awkward, and inconvenient, that I think nothing but an absolute necessity ought to induce the re-building of it in the same place. That it will cost more in this new situation than in the old one is very certain, and to do it completely, considerably more than Mr. Jessop has estimated, but then it will render the navigation more complete; this is a circumstance, which, with the present trade upon the rivers, and particularly at this critical passage, should outweigh all small considerations: besides, the comparison, in point of expense, ought not to be made between building the lock in the old, and in the new situation, but between building the lock upon the new cut through the marsh with all convenient expenses, and rent charges thereto incident, and in the new situation; and when these matters are duly weighed, it would seem, that judging upon the surface of the thing, the business may be done as effectually, and upon the whole, at as little expense, by adopting the new situation as by making a new cut through the marsh. The principal difference will be, that a new lock upon a new cut will not obstruct the navigation at all, because it may be opened while the other is passable, but then, though the obstruction to the navigation might exceed a week which Mr. Jessop has proposed, yet there is an equal probability of the re-building of the locks exceeding four weeks, so that we may fairly lay the account of the lock's re-building where it is, to produce obstruction of full three weeks more than the present, than in the new situation, and the former when done, a much worse lock, because built more in a hurry, and without the necessary time for the masonry to settle and harden.

I would therefore propose, in order to make the best of the new situation, to place the lock further down, and nearer the natural deep water than proposed by Mr. Jessop
by

by the full length of a lock, and instead of a double wall with a rib of earth between, to build a solid aifler wall, well founded upon piles at the level of the tail-water, of about eight feet thick at base, and six feet at top, with a solid caping of single stones cross and cross, and well cramped together. This wall, reaching from the old lock-tail to the new lock-head, I suppose will be the only extra expense attending the new situation, which, as near as I can compute, will amount to about per rood, running measure, and though we reckon ninety yards length instead of fifty, which, calling thirteen roods, the whole will amount to no more than about £ to balance which, on one hand we save the value of three weeks stoppage, and have the advantage of a bason that will hold a considerable number of vessels, and on the other we save the purchase or annual rent of land, part of the digging of the cut, and possibly the expense of flood-gates at the head of the cut, which, if needed, may here be easily applied at the old lock.

As a further improvement and safety to the entry of the present lock, being too near the dam, I would propose to drive about six large piles, reaching about three feet above common water, and caped with a rail, so as to lead in the vessels in the same manner as if the cut had been so much longer, these being at twenty feet distance, will make in the whole one hundred feet extension.

It has been suggested by Mr. Martin, that the having two locks, or separate passages, would be very advantageous, particularly below the junction of the two rivers, not only for facilitating the passage of the numerous vessels, but that one lock might be open, while the other was closed for repairs; and this circumstance would doubtless still give the preference to a cut through the marsh, if it could be obtained, but as the chief difficulty as I understand has laid amongst the land owners, having right of common upon the marsh, it appears to me, that provided the flood-wheel of Brotherton's mills were taken away, there would then be room for making a new and separate additional lock and passage, parallel to the present one, still leaving the other two wheels of Brotherton's mill, that are in common used, standing for use where they are; and in case this supplemental lock were first constructed, then the alteration and removal of the present lock would be done at leisure without any stoppage, or any other inconvenience than the expense of building the supplemental lock.

J. SMEATON.

Austhorpe, 29th August, 1778.

SOWERBY

SOWERBY BRIDGE CANAL.

The OPINION of JOHN SMEATON, engineer, respecting the best way of supplying the Sowerby Bridge cut with water from Holling's mill.

MY idea always was to bring the water through the high grounds, by means of a tunnel made in the way of an adit or fough, such as those made for draining collieries, which I would recommend to be done as follows; beginning from some proper place near the head of the canal, and in the straightest direction, that one or more staples or fough pits can be got down, and the matter coming thereout can be disposed of, to carry on the same so as to come out at the day into the holme, that begins on the north side of the river just above Sowerby bridge, then to go on by an aqueduct cut along the skirt of the high ground, till you begin to interfere with the tail race of Holling's mill, then you set in an adit again, and go under or round the north end of the mill, and so into the head. This is the general outline of the project which I have formerly communicated; what is now particularly to be mentioned is, that I would begin the tail of the tunnel or adit, so low that its bottom shall be at least as low as the bottom of the canal, which the descent to the river there will easily admit of a trench to clear any water that shall be raised in carrying on the tunnel; the bottom of the tunnel to be carried on upon as dead a level as possible, or to allow for a better current you may begin upon a lower level; but as it will take too great a length of time to carry it on wholly from the tail upwards, I would advise the tunnel to be begun at both ends, and meet in the intermediate way.

The west end of the tunnel may be begun about three or four feet below the level of Sowerby bridge dam's water, and being furnished with a short pump to raise the water about six feet, the drainage water will probably be overcome by pumping half an hour at the beginning of each day, and now and then when wanted, to carry this upon the deadeft level they can, and at the meeting to reconcile the two drifts together, by taking away all sudden turns, humps, and elbows; it is possible that a considerable quantity of water may be raised in this tunnel, which will in part supply the navigation, and which they can call their own; and it is also possible, that the tunnel may prove so full of springs, as to make pumping for the head of it too expensive; if this should be the case, its bottom may be carried upon a level about six inches above Sowerby bridge dam's water, so as to clear itself, and the bottom may easily be cut down after
the

the meeting, so that the whole drainage will go off by a natural descent at the tail. The adit or tunnel at Holling's mill I would also advise to be begun by another set of men at the same time, beginning from the tail, about a foot above the common tail water of Holling's mill, and running in upon a dead level; in the face of the bank, just above the mill, to put down a staple or fough pit, and to carry up the drift to this pit; in this pit you must establish a good clough or sluice of about two feet wide, and when the whole is completed and secured, cut away from the pit into the mill head.

While the above is doing, another set of hands may be making the opencaft, which will be best if its bottom is inclined, so as to reconcile itself with the tail of the mill tunnel, and the head of Sowerby bridge tunnel, but if the ground will not readily admit of this, its bottom may be kept upon a higher level; however, no part of it should be upon a higher level than four feet below Holling's mill dam-head. When the tunnel and aqueduct are completed, they may be joined by banking up the tail drain of the mill tunnel, and the water, in rising to its level, will find its way down the aqueduct, though its bottom should be higher than that of the tunnel; and a small shuttle or sluice being established upon the tail drain of Sowerby bridge tunnel, the water will be forced into the canal by a proper aqueduct, either open or covered, that must be prepared to give it passage, and by having a shuttle upon this last passage, the water may be let out of the tunnel at any time, in order to repair or alter any thing without letting off the canal.

I covet to lay the bottom of the tunnels so much lower than might seem necessary, because, as it can be done at the same expense, the pumping excepted, it will avoid all extra expense in making them larger than they must unavoidably make them to work therein; for by this means the tunnels being in a manner filled with water, they will vent a great quantity upon a small difference of level from first to last, the water always tending to rise to its own level; whereas, were the bottom made even with the surface of the canal, the water running then upon the bottom will require not only a considerable width to carry a quantity, but there will be a good deal of level lost to make it run, inasmuch, that the whole would scarcely be sufficient. I also covet the water ways to be thus ample, not that I suppose any considerable quantity will be wanted in ordinary from Holling's mill, but that the canal on any occasion of emptying it may be again filled in a short time upon an emergence.

A sluice will be proper at the head of the bridge tunnel to prevent the floods from making a passage through it, and the aqueduct having its bottom made about four feet wide

wide, with proper slopes, may afterwards be walled at three feet, or covered at two and a half feet wide, but I think it will be best to leave the aqueduct open at first, till it is seen how it acts, and that if any amendment is necessary (which can easily be done while open) it will be best done after trial.

If any part of the tunnels want walling, I would by all means have them made sufficient for a man to get through, and the staples, one at least in the middle, to be walled, and properly covered, so as to be used on occasions.

J. SMEATON.

Austhorpe, 14th January, 1772.

QUERIES

DUBLIN GRAND CANAL.

QUERIES from the company of undertakers of the Grand Canal, as amended and approved the 3d day of August, 1773, and ordered to be laid before JOHN SMEATON, esq. engineer, and F. R. S.

YOUR approved integrity and abilities as an engineer, induced the company to request you to come to Ireland and inspect the line and tracts proposed for the intended navigation of the Grand Canal from the city of Dublin to the river Shannon, and also for the collateral canals to the Boyne and Barrow, with so much of the river Barrow as lies between Portarlinton and Athy, and personally to view the country adjoining to these tracts, and to report in writing the lines you would recommend, and the plans according to which you would advise the undertakers to proceed in making them navigable, and to advise what you think necessary, not only with regard to the construction and dimensions of the locks and navigation, but also the mode of conducting and carrying the same into execution, in the most effectual and expeditious manner, for the common good of the kingdom, and the interest of the undertakers; and though we are confident, that in so doing, nothing material to our interest, or for the general improvement of this kingdom, relative to this subject, that can occur, will escape your notice, or pass without being fully represented to us, yet we are desirous (among other matters which you may think necessary) of having the following questions particularly considered, and as fully answered as the nature of them will admit.

QUERIES.

1st. How and where would you advise that the canal should terminate next the city of Dublin? Here you are to take into consideration the different kinds of merchandise and manufactures which are likely to pass by the canal, and, whether for such goods it will be necessary for the company to erect any, and what kind of wharfs, warehouses, toll-houses, or other offices, contiguous to the termination, and where, and what avenues and passages may conveniently be opened from thence to the different parts of the city?

2d. Do you think it would be of general advantage to make a navigable communication between the canal and the harbour of Dublin, so that goods passing by the canal (particularly such as are imported, or to be exported) may be subjected to as little

little land carriage as possible? if so, you are to say where, and of what dimensions, and in what manner you would recommend such a communication to be, and to consider the quantity of water that will be necessary for its supply. Several tracts have been proposed for the communication, between the canal and the harbour of Dublin; in particular, one, nearly in the same direction as the new environ road, one to pass the city basin, and to cross Thomas-street, near Crane-lane, and to terminate near lord Moira's house, and one to cross James's-street, to enter the Liffey opposite the barracks; the others will on enquiry be pointed out to you.

3d. Is there any part of the present cut for the canal (between the city of Dublin, and Sallin's-bridge, near the Liffey) from which you would now advise a variation?

4th. There are three places pointed out as proper for crossing the river Liffey, the first near Chain-bridge, by which means it is said, the deep sinking on the high ground, or hill of Downings, would be avoided, and a very considerable expense saved thereby to the undertakers. The second is at Waterstown Ford. The third the present line. You are therefore not only to examine them, but also the river up and down stream, and to recommend the place which shall appear to you most for the company's advantage. You are likewise to say how the canal should pass that river, whether by a dam or penlock, or by an aqueduct bridge; if by the latter, give the dimensions of it, and what additional works may be requisite there.

5th. There are three ways proposed for avoiding the high ground of Downings, beside that mentioned in the foregoing question: First, by carrying the canal from Sallin's to Carrah-bridge, and there crossing the river. Secondly, by continuing the canal further up the east side of the river, to cross at Gammonstown, and through the bog of Donore, to the Blackwood river. Thirdly, by departing from the present line at Aughpadin, and passing by Killebegges and Blackwood. You are requested to be particular in examining those three passages, and to give your opinion whether it would be most for the advantage of the company to adopt one of them, or to carry the canal through Landenstown, Downings, and Graig, in its present direction. You are to observe that the hill of Downings is a clayey lime-stone gravel, and to say whether any, and what use may be made of it on the bog of Allen?

6th. If you think it expedient that the canal should be continued in the present line to the Blackwood river, would you advise sinking it through Landenstown, Downings, and Graig, to the same level as at Sallin's-bridge, as by that means some lockage would

would be saved, the canal of partition made much longer, and the Morrell, with part of the river Liffey, brought to the point of partage?

7th. Whether you would recommend carrying the canal in a tunnel or arch through the hill of Downings, or making it an open navigation?

8th. You are to consider the nature of the bog of Allen, and say, whether you think a permanent canal can be made through it, and the methods you would recommend to effect it?

9th. You are to examine the line (as marked out) from Downings to Lullymore, and say, whether the canal can be carried in that tract on one level quite through the bog, or how many different levels will be necessary?

10th. You are to examine whether the low part of the bog, between the Cussh and the Figuile rivers may not be avoided, and the canal of partition carried several miles farther than in the present line, by passing from the wood of Allen towards Edenderry, and north of river Lyons, to or near Philipstown, and also, whether a more favourable passage to the river Shannon cannot be found, than through the high grounds of Knockvalleybay, and by the Maiden and Brusna rivers, and whether you would advise this junction by a canal, or clearing the Brusna where it is not navigable?

11th. There are three tracts proposed for the cut of communication between the canal and the river Barrow. First, from Cardiffstown or Sallins by Naas, in nearly a right line to Athy. Secondly, along the Blackwood river to enter the Barrow at Monstereven. Thirdly, by a cut from the canal between the Cussh and Figuile rivers, to enter the Barrow near Portarlinton, you are therefore to say, which of these you would recommend, or what other, and mention the depth and dimensions you would recommend for this collateral canal and its locks, and for boats of what burthen?

12th. There are two tracts proposed for the collateral branch to the river Boyne, one from the canal near Lullymore to Edenderry, the other by the Black Water, give your opinion which of these the company ought to adopt, or what other, and mention the depth and dimensions you would recommend for this collateral canal, and its locks, and for boats of what burthen?

13th. What harbours, wharfs, and warehouses do you think necessary at the great roads where they are intersected by the canal, and where it is probable, goods may be loaded or unloaded ?

14th. Do you think lock-houses are necessary, mention their uses ?

15th. What probable quantity of water will be necessary for the supply of the canal, what depth and dimensions would you advise the canal to be made, and what burthened boats would you recommend ?

16th. Do you think the Blackwood river sufficient for the supply of the canal, if not, you are to say from whence you would propose drawing the greatest necessary quantity, and at what probable expense ?

17th. If you think part of the river Liffey necessary, would you advise taking it up at Gammonstown, and to enter the canal at Sallins, or to draw it from New Bridge round Rasberry and the island of Allen to the canal of partition, at the Blackwood river, or where else ?

18th. If you think the Morell river necessary, please to say how, and where you would propose that it should enter the canal ?

19th. Will there be reservoirs necessary, if so, where, and of what dimensions ?

20th. Do you think it the interest of the company to begin the works at, or west of Downings, before those from Dublin to Aughpaddin shall be finished, and be so good to advise the particular parts of the navigation you would recommend to be first executed ?

21st. Is it necessary to have convenient places on the canal during its execution wherein implements, &c. may be safely deposited, or do you think the company's general stores in Dublin entirely sufficient and convenient for that purpose ; may not the Dublin stores be fixed on the line ?

22d. After receiving full information and satisfaction, relative to the materials which the company can conveniently procure for the locks and other works, you are requested to give your opinion of them, and in particular, to say, whether building them of
stone

stone squared or dressed with the hammer (copeing quoins, cove and other particular stones excepted) would not prove sufficiently permanent, and more to the advantage of the company, than by building entirely with cut or chiseled stone.

23d. You are to give your opinion of the permanency and construction of the locks now building for the company, near the city basin, by Mr. Trail, as well as those built by Mr. Omer, at Clonaughlefs, Ballykealy, and Clonburrowes.

24th. In giving your opinion upon the above queries, you will consider and declare your sentiments, whether the parts of the line already cut, and the works done thereon, are of such use and benefit, that it will be most proper and advantageous to go on and continue them, or in any and what places, and how deviate from them?

25th. If there occur to you any convenient places on the line for mills, bleach-yards, or any other, and what benefits that may arise to the company from the canal water banks, land, &c. be so good to mention them, and also if you would recommend a turnpike road to be made on the banks of the canal, and in what manner? note, the company by their act of incorporation have a right to erect turnpikes.

26th. There is a contract between the city of Dublin and the company, that the city basin should be amply supplied with water for the use of the inhabitants: how and in what manner would you recommend the company to provide for that supply of pipe water?

27th. It is submitted to you, whether for the reasons that will be mentioned to you, instead of endeavouring to avoid the bog of Allen, it will or will not be much for the advantage of the company to carry the line as far through it as can be done with propriety, and whether the draining and improving that great waste by means of the canal running through it, will not also be a matter of great national utility?

The REPORT of JOHN SMEATON, engineer, upon his view of the country through which the Grand Canal is proposed to pass, and in answer to several matters contained in the queries of the company of undertakers of the Grand Canal, as agreed to on the 3d of August, 1773.

(1.) HAVING carefully perused the matter contained in the queries, which the company of undertakers of the Grand Canal have done me the honour to lay before me, and having examined the face of the country through which the lines of this very extensive scheme of navigation are proposed to pass; a scheme so extensive, that it has taken fourteen days merely to go over the ground; and though it cannot possibly be expected, that in so small a space of time I can give a positive and distinct answer, to all the several matters contained in the said queries, which, in fact, comprehend the modelling of the whole of this great project, which I could scarcely undertake to perform with accuracy, and upon my own knowledge, in twelve months of uninterrupted attention; yet from the view that I have taken, and the assistance that I have received, from the several plans, sections and papers that have been put into my hands, relative to the affair, as well as from the personal attendance and information of Mr. Trail, the company's engineer, I find myself enabled to pass some general judgment upon the outlines and leading marks of the great design before me; and as I doubt not, but that the company will be desirous of being acquainted with my sentiments as early as possible, I will endeavour to throw together the principal matters that have occurred to me, in as short a manner as possible; and as I find I can do it in a shorter way, by a consideration of the whole matter before me, than by pursuing the queries in the particular order in which they are stated, I beg leave to do it in this way, for the present, reserving a more particular discussion of the matter contained in the queries, to a future report, to be made more at leisure, and upon such further surveys and enquiries, as may be thought necessary by the company, in consequence of what is suggested in this present report.

(2.) In the first place I beg leave to observe, that the execution of a scheme of inland navigation, is of all others the most embarrassed with obstacles and difficulties, arising from a difference of interest, property, and opinion, which increase in proportion as the design is more extensive. I perhaps shall not be wrong in saying, that no very extensive enterprise of this kind has yet been brought to a completion, even where opposition of interest and opinion may be supposed in a great measure out of the

the question.—The Czar Peter, after a very great expense, and carrying on his works to a great length, was obliged to lay aside the execution of his great project of a canal from the Volga to the Don, and which has never since been resumed: and the canal of Languedoc, though driven through by Louis XIV. at the expense of above £600,000 sterling, was at last terminated, though a canal of six feet water, in a river that in dry seasons in summer for a great extent has not above three feet of water; and to remove which defect, it has been computed by the French engineers, it will cost a further sum amounting to £50,000, so that even this canal may be said to be incomplete as to execution; and it is very certain, that as to revenue over and above repairs, it is so small that it bears no proportion to the interest of the capital expended.

(3.) The greatest fault of the plan now before me, is, that (as it appears to me) it is too extensive; I cannot help therefore most earnestly advising the company, to confine their proposition for the present, to some one point of view; and to take that which is most immediately and most certainly likely to turn to advantage; provided that it be carried on in such a way as that the first plan may be capable of extension; for one proposition carried through to satisfaction, is the most likely way to produce a further extension, and gradually to get the whole into execution.

(4.) From every thing I have seen, heard, and read, concerning the trade that is likely to be carried on upon this canal, I am of opinion, that flat-bottomed vessels from thirteen to fourteen feet wide, fifty-six feet extreme length, stem and stern post, and drawing from three and a half to four feet water will answer every purpose:—such vessels, even if decked, and not made unnecessarily heavy, will carry thirty-three tons neat weight.—I choose vessels of this construction rather than those more narrow and long, because they are better adapted to sail in the tide ways, and in broad lakes, whenever the canal shall be brought down to the Liffey at Dublin, or extended to the Shannon, which I think are points always to be kept in view:—open boats, lighter built, of the above dimensions will carry above forty tons; and it seems to me, that vessels not exceeding these sizes will answer the purposes of the trade of the country better than larger, because they will be less detained in getting a loading to or from any particular place, will make more quick returns, and be more easily managed: it is indeed not possible for me in a small space of time to have a comprehensive view of the trade, manufactures, and connections of a country; but this I know, that the artificial navigation, which of all those in England has turned out the greatest profit to the undertakers, and does the most business, (which is that of the Aire and Calder in Yorkshire) is carried on in vessels not exceeding the above dimensions.

(5.) The

(5.) The size of the largest vessels being fixed, the size of the canal and locks will be determined thereby, viz. the locks to be fourteen feet wide, sixty feet long in the clear pool, and four feet one inch of water over the thresholds.—A canal for such vessels where there is no extra digging or hardness in the soil; in order to enable the vessels to pass one another, and move freely, should be dug to a twenty-four feet bottom, with slopes or batters as three to four, that is, to fall back four feet, in three feet perpendicular; and to be dug to four feet nine inches depth of water, when there is four feet one inch over the lock thresholds: but where there is extra cutting, hard matter, or rock, the bottom may be reduced to a less width, that is, to twenty, eighteen, or even sixteen feet; but then if those contractions are extensive, passing places should be made in the most favourable parts; and the depth may in rock be reduced to a little more than the lock thresholds.

(6.) The grand canal, as it has already been dug, is in general not wider than necessary for vessels of the dimensions specified; but on the contrary, in many places is more contracted than I should have laid it out. I do not find, however, any place too narrow to admit of the passage of such vessels; and though it may be proper to widen some of them, yet I would recommend to make as few alterations as possible in the present works. This reduction proposed in the draft of water, from what was originally proposed, viz. five feet three inches over the lock thresholds, and six feet in other places, will, I apprehend, make a considerable difference in the expense, not only of finishing the works that have been begun, but those that are to be done; as I have found that more expense attends the making and maintaining depth of water than width.

(7.) In the next place I beg leave to acquaint the company, that I have viewed all the courses pointed out in the several queries, for obtaining a passage from the east country into the bog of Allen; but as I observe that a continued chain of high ground, stretches itself on the west side the Liffey from north to south, they differ only in being more or less high, more or less broad, or more or less round about;—had the course of the canal been undetermined, no money laid out, or lands purchased upon any of these passages, I might have hesitated in determining my choice upon ocular inspection; and might have caused surveys and sections to be made of others, as well as the present course through the high grounds at Downings; but when I consider that what cutting has been made there will be in aid of what is to be done, together with the grounds purchased and paid for; I see no way of avoiding this passage now, but what will in effect be the changing a less difficulty for a greater: it seems therefore most eligible, to make the best of this passage: but if any gentleman that has
pointed

pointed out any of the several ways mentioned, to avoid the deep cutting at the hill of Downings is unsatisfied by this opinion, which is the best I can form upon ocular inspection only, I am now from this view enabled to direct such surveys and sections to be made, as are necessary to determine the affair upon scientific principles.

(8.) Finding, previous to my view, the passage at Downings every where mentioned as a hill, it seemed extraordinary that any one should think of going through a hill, if they could go round it; but as I have already mentioned, here is a chain of rising grounds, and this is the lowest neck between two of the more elevated rises, that is most directly in the line, and shortest; and I am not sure that it is not the very lowest and most eligible, even if nothing had been done. The deep sinking in the rocks at Gollerstown, I think might have been in a great measure avoided; but as this difficulty is in great part overcome, it does not seem now proper to depart from it; I cannot, therefore, now advise any part of the line to be varied from the city of Dublin to the entrance of the bog of Allen. As I look upon bogs to be an uncertain soil to form canals in, and to be avoided as much as possible, this, together with the great extent of it, between the hill of Downings and Philipstown, and the irregular surface thereof, greatly enhances the difficulty; and adding to this the low bog between the Cushaling and Figuile rivers, which will either occasion two summits of partition, or a great increase of deep sinking at Nockballyboy (being a summit west of Philipstown, and which I see no adequate means of avoiding), I say that those difficulties put together, are so great objections to the present line from the Togher of Graig to Philipstown, that I can by no means recommend a canal to be executed thereupon.

(9.) In consequence of what is suggested in the 10th query, I have reconnoitered the country north of the present proposed line from the Togher of Graig to Philipstown, and as closely as the season of the year, the wetness of the bogs and time would permit; and it seems to me that a line more favorable than the present proposed one may be found by traversing from point to point upon the skirt of the high ground, called the Wood of Allen, and from thence passing that part of the bog near the head of the Boyne towards Edenderry, falling in with the island of firm ground called Derryfadod; and from thence either through the hollow on the north side of the hill of Ballykillin; or, if that shall occasion too much deep cutting round the skirt on the south and south-west side of the said hill, to the north side of river Lyon's house, and from thence keeping nearly parallel to the Figuile river to Philipstown, by which means the very soft bog on the south of river Lyon's house will be avoided. This course it will be proper to have particularly examined by the level, and as it will take up some time, it should

should be at a favorable season of the year, when the bogs are more dry; a section and plan to be made thereof, which, from the view that I have had of the country, I shall not only be enabled to judge of when done, but to give some more particular directions for the doing thereof when thought proper by the company. According to this idea, the canal of partition, if found favorable this way, will extend from the east side of the deep cutting at Downings to the west side of the deep cutting at Nockballyboy, which will probably be a course of about twenty miles; and in this district all the difficulty lies; for, after getting through the neck of the last-mentioned summit, the ground lies as favorably as possible to Tullimore, and from thence by the valley in which the Maiden and Brusna rivers have their course to the Shannon. Those rivers at the time of my view overflowed the valley in many places, so as to make it impracticable to pursue them closely; but as the valleys in which they lie are in general open, with flat grounds on each side, there cannot occur any considerable difficulty; the principal will be in cutting through a summit a little above Firbane to avoid the mill-race and eel weirs about that place. After the Maiden joins the Brusna, it appears by the plan and soundings of the river taken by Mr. Trail, that long stretches of deep water occur therein; it seems, therefore, a saving of expense where these occur, to make use of the river; but where mills, weirs, shoals, and other impediments to navigation occur, that cannot easily, or with certainty, be removed, there the best and often the only practicable way is to cut a canal with locks upon it, by them; and if the present proposition of reducing the navigation to boats drawing no more than four feet water, be adopted, it will occur, that the length of several of the canals may be shortened, and thereby expenses saved.

(10.) Respecting the junction of the river Barrow, after the canal is carried to the Togher of Graig; as I have already advised a new line to be surveyed more to the north than the present, the branch for the Barrow will most naturally here divide, and go by the tract of the river Blackwood to the Barrow, in which space there seems not the least impediment to the passage of a canal, or any extra expense likely to attend it, except in passing the town, and some ground a little too high at Rathangan; and as the whole course of the Barrow from Portarlinton to Athy lies very flat, the whole may be connected by navigable passages at a very moderate expense, in proportion to the extent of country, whose produce will be hereby brought to communicate; so that if it be true that as great a trade will be carried on with Dublin from the Barrow as from the Shannon, I cannot hesitate in advising the company first to complete a navigation to the Barrow before they begin to work from the Togher of Graig towards the Shannon, and that for these reasons:

(11.) As

(11.) As the junction with the Barrow will at any rate cost much less than the junction with the Shannon, the company will be able to make a much better dividend of profits upon their outlay than if they go to the Shannon.

(12.) If the dividend is good, this will of all others be the greatest inducement to go afterwards to the Shannon, if bad, it will prevent the company from embarking in a scheme that would turn out to their detriment.

(13.) If the company have money to execute one, and not both, that which will turn out most profitable to themselves, will be so to the public.

(14.) If the company have money to execute the less and not the greater; the executed scheme will make a good return, and be of great use; but the unexecuted scheme will make very little, if any, return, though it may be of some small use.

(15.) I doubt not but that with the sum of money that the company can rely on, they may complete their works to Athy; but yet I would advise the strictest economy that a large company can possibly use, to be put in practice; and then they may have something to spare towards the Shannon; but I cannot undertake to say as much, if they proceed first for the Shannon, even if the line now proposed should turn out favorable.

(16.) On the head of economy I cannot help taking notice, that there is nothing so conducive thereto as unanimity. I have had occasion to observe, that the worst way of doing a thing, if carried on with unanimity, will often be attended with less expenses than the best, if the execution is distracted by a variety of opinions; perfect unanimity in a company, consisting of many members, is not to be expected long together; but it would have nearly the same effect, if it were possible for the minority to think themselves bound by the opinion of the majority. I ask pardon for launching out upon a subject not so immediately a part of my profession, but as the company desire me in general terms, to point out whatever may be for their benefit and advantage, as well as those of the public, in carrying this grand undertaking into execution, I could not help seizing the opportunity of pointing out what is of the greatest consequence of all others.

(17.) It seems to me, that the first thing to be aimed at is to complete the navigation from its present termination, near the city basin, to Sallin's bridge; and a ware-

house of a moderate size being built at each end, it may be expected that the greatest part of the goods that now go by land from the south-western parts of the kingdom, would come upon the canal, and bring something in; and probably some species would come that do not now come at all, of which turf may be one. A considerable warehouse will be wanted in time at the Dublin termination, but warehouses may be added as they are wanted.

(18.) I have viewed all the ways proposed for joining the canal with the Liffey at Dublin, and all are practicable, of which I doubt not but that by the environ road will be the most expensive; but were it least so, I think it most liable to objection, because the navigation by the other routs being carried by the Liffey through the heart of the city, thereby all the warehouses, upon the very extensive quays on each side of the river, would become so many warehouses for the navigation, so that none would be necessary on the company's account. Of the others; that by crossing James's-street, to enter the Liffey opposite the barracks, seems, at present, the least encumbered and the most direct course: but as the going down to the Liffey will, at any rate, be attended with a great expense, and as the several avenues to the town will be connected by the environ road, and the present termination of the canal, I am of opinion that the joining of the Liffey should be the last thing done, and not till the circumstances of the trade of the Grand Canal shall, from actual experience, shew it to be necessary.

(19.) I should hardly propose the moving westward, till the navigation to Sallin's bridge was completed; but as the cutting the neck of the hill of Downings, (or the making good any other passage through that chain of hills), will take up a considerable time to do it with proper economy, I would advise to recommence the work there; and I believe that not only boats at each end of the deep cut, but machinery, might be employed in the middle to good advantage. I believe it would be right to keep a separate account of the work west of Liffey, by which means the company will be enabled to see what expense it costs to complete the works, delivered over to them between the city basin and Salin's bridge.

(20.) The masonry of the locks now building by Mr. Trail, near the city of Dublin, appears to me to be done in the most permanent and substantial manner; I cannot say the same thing of those at Clonaughless, Ballykealy, and Clonboroughs; but I do not think the necessary degree of firmness in the last-mentioned locks, so much deficient on account of the sort of masonry made use of, as the want of proper method and proportion. The sort of marble wherewith all the locks are built, I perceive is very expensive to
chisel

chisel fair; otherwise I should not recommend the use of any thing but chiseled stone in the face of the work: I perceive, however, that the best species of hammer dressed work will stand very well, especially if set with good cement, which, indeed, is the very essence of good masonry. I saw a lock upon the Shannon, about three miles and a half below Banagher, which has been in use eighteen years, is built with the same kind of stones, hammer dressed, and has stood very well; I understand it was built by Mr. Omer; it is in the same stile of work as those at Ballykealy, &c. but is only eighteen feet and a half wide, whereas those at Ballykealy, &c. are twenty. The lime of this country seems very good, particularly for dry work; the lime used in the Shannon lock, which, I think, has stood better than that at Ballykealy, &c. has not washed or decayed by the water, but had not acquired a stony hardness; for this reason I would recommend the use of pozzelana, which has been imported from Italy to several of the works that I have been concerned for in Great Britain, at the price of forty-two and forty-three shillings per ton; as it comes much cheaper than terras, it can be made a more liberal use of, and as it is in many respects preferable, it will greatly contribute to the establishment of good masonry: I therefore think, that, considering the great difference here between hammered and chiseled work, and that it seems requisite to reduce the expenditure upon the locks, whenever it can be consistent with that duration and permanency which they ought to have; that good large hammered work, interspersed with good bond-stones in every course, jointed and pointed with pozzelana mortar, the quoins, fell-arches, cove-stones, and coping being chiseled, will produce work sufficiently durable, and more to the profit of the undertakers, than expending large sums of money in constructions, that though more perfect, yet such as in point of utility the difference will hardly appear in fifty years.

(21.) Respecting the communication with the Boyne, as I have recommended the line to go nearly to the head thereof, and as the Boyne runs in a very flat course till it is past Edenderry, it is plain that a junction therewith, in the line proposed, will be practicable; and this, considering the scope of my advice to the company, to have only one immediate point in view, seems to be all that it is now necessary to say about it.

(22.) I have viewed two passages from Sallin's bridge to Athy, without going through the Downings, and beside the appearance of a want of water at the summits, will cost more than the passage at Downings, and as this passage would leave the extension to the Shannon quite out of the question, on all these accounts, I look upon the proposition
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of a direct passage from Sallin's bridge to Athy, if not practicable, at least as very ineligible.

J. SMEATON.

Dublin, 6th October, 1773.

(23.) P. S. There is no doubt of the practicability of bringing a sufficiency of water to the point of partition.

J. S.

Navigation-house, October 6th, 1773.

At a meeting of the company of undertakers of the Grand Canal,

REDMOND MORRES, esq. in the chair,

Resolved—That a committee be appointed to take Mr. SMEATON's report into consideration; any five of whom to be a quorum.

And a committee was accordingly appointed and ordered to meet to-morrow morning, at ten o'clock, for that purpose.

Navigation-house, 7th October, 1773.

At a meeting of the committee appointed to consider Mr. SMEATON's report,

Mr. EDWARD STRETTELL, in the chair,

THE committee appointed to take into consideration the report of John Smeaton, esq. engineer, who attended in compliance with the desire of the company, on the 6th instant, having requested his opinion of the best line wherein to carry the Grand Canal from the hill of Downings to the river Shannon, the junction with that river being the great object which they have most particularly at heart, he recommended a survey to be immediately taken of the ground, as mentioned in his report, in answer to the tenth query,

query, from the Togher of Graig, in the bog of Allen, to Philipstown, as he expects that the said new line will be executed with greater certainty, much sooner, and at less expense than that formerly proposed through the bog of Allen; and Mr. Trail having declared that he fully agreed in the same sentiment, the tenth query having been for that reason suggested by him, it was resolved to be the opinion of the committee, that Mr. Trail and Mr. Jeffop should be furnished with instructions to proceed immediately upon the said survey.

GENTLEMEN,

I NOW sit down to give you a more particular answer to the queries than you did me the honour to put into my hands in the month of September, 1773, when from the want of time, and some circumstances necessary to be ascertained for the forming my opinion at large, after a general view of the premises (which was taken in fourteen days) I was then enabled to do; but yet, upon which view I took the opportunity of suggesting some of the great business relative to this business in the report then made to you, bearing date 6th October following; and though a considerable length of time has elapsed since the date of that report, and several steps have been taken by the company in consequence thereof, which is some report, which is some report, yet as the grand point then in view, of carrying the navigation from Dublin to the Shannon, still stands an undetermined question, both as to the absolute practicability thereof, and as to the most practicable and advisable road of carrying the same into execution, I better myself that what I now have to say will not come out of season, or be less to the purpose on account of the length of time that has elapsed, which has in fact put it in my power more narrowly to weigh and consider the circumstances attending, and likely to attend, this business. And as my said report of the 6th of October, 1773, contains a considerable quantity of matter in answer to the subject of those queries, and as this report has been printed, together with the said queries, which I conclude is in every one's hands any ways interested in this matter, to avoid unnecessary repetitions, I shall, in this further report or answer to the said queries, occasionally refer to the said printed copies of both; and that we may go on more smoothly together, I must desire that the said queries and report may be laid before you, and that you will take the trouble of numbering the paragraphs of the report from one to twenty-two (exclusive of the P.S.) to which, by this means, I can more easily and readily refer, and though I have now several matters to touch upon, which will not come properly in direct answer to any of the queries, yet as in the preface to the company's queries I am desired, in general words, to report, in writing, the lines I would recommend, and the plans according to which I would advise the undertakers to proceed

IRISH

The FURTHER REPORT of JOHN SMEATON, engineer, in answer to the queries proposed by the company of undertakers of the Grand Canal, the 3d of August, 1773.

To the court of directors of the Grand Canal, Ireland.

GENTLEMEN,

I NOW sit down to give you a more particular answer to the queries that you did me the honour to put into my hands in the month of September, 1773, than from the want of time, and some circumstances necessary to be ascertained for the forming my opinion at large, after a general view of the premises (which was taken in fourteen days) I was then enabled to do; but yet, upon which view I took the opportunity of suggesting some of the great outlines relative to this business in the report then made to you, bearing date 6th October following: and though a considerable length of time has elapsed since the date of that report, and several steps have been taken by the company in consequence thereof, which in some respects alter the face of the business, yet, as the grand point then in view, of carrying the navigation from Dublin to the Shannon, still stands an undetermined question, both as to the absolute practicability thereof, and, as to the most practicable and adviseable road of carrying the same into execution, I flatter myself that what I now have to say will not come out of season, or be less to the purpose on account of the length of time that has elapsed, which has, in fact, put it in my power more maturely to weigh and consider the circumstances attending, and likely to attend, this business. And as my said report of the 6th of October, 1773, contains a considerable quantity of matter in answer to the subject of those queries, and as this report has been printed, together with the said queries, which I conclude is in every one's hands any ways interested in this matter, to avoid unnecessary repetitions, I shall, in this further report or answer to the said queries, occasionally refer to the said printed copies of both; and that we may go on more smoothly together, I must desire that the said queries and report may be laid before you, and that you will take the trouble of numbering the paragraphs of the report from one to twenty-two (exclusive of the P.S.) to which, by this means, I can more easily and readily refer, and though I have now several matters to touch upon, which will not come properly in direct answer to any of the queries, yet, as in the preface to the company's queries I am desired, in general words, to report, in writing, the lines I would recommend, and the plans according to which I would advise the undertakers to proceed

ceed in making them navigable, and to advise what I think necessary, not only with regard to the construction and dimensions of the locks and navigation, but also the mode of conducting and carrying the same into execution in the most effectual and expeditious manner for the common good of the kingdom and interest of the undertakers. Under these general directions I shall beg leave (after answering the queries, one by one, with references as aforesaid) to subjoin what I have further to offer upon this subject.

1st. Answer to query 1st.

The several objects of this query are local circumstances, which it requires to be well acquainted with the different kinds of merchandize and manufactures of the kingdom of Ireland, that are likely to pass upon this canal, and the situation of trade in the city of Dublin, to answer properly, which the short stay that I had it in my power to make did not enable me to become; and at last it is rather a question to be answered by merchants, traders, and manufacturers, than by engineers. It does not, however, to me appear, that on supposition of the canal not entering the city itself, its present termination is ill chosen, and, at any event, a large wharf and warehouses will be wanted at the present termination. I would advise to begin with a very moderate one at first, to be added to as occasion shall require, but to be positively ready as soon as the navigation shall be completed from Sallin's bridge, to the present termination at Dublin. For I find nothing so common, after much impatience in getting a stretch of navigation completed, in a great measure to lose the use of it for some time for want of warehouses at both terminations; but a very moderate one will always do at Sallin's bridge, as the navigation is proposed to go further. See report, paragraphs or articles 17th and 18th.

To the 2d.

This is almost fully answered in article 18th, so that it is only necessary to add, that the water that brings vessels from Sallin's bridge will lock them down to the Liffey, and as many vessels, notwithstanding such communications, will yet deliver at the present termination, and return west, there will be a redundancy of water at the present termination.

To the 3d.

This is fully answered in article 8th.

To

To the 4th and 5th.

See what is said in article 7th, and first part of the 8th, to which I must add, that the only question remaining in query 4th, is, where to cross the Liffey? whether at Waterstown ford, or at the present line, and how to be crossed? respecting the latter I have at present no doubt, but that it will be best crossed upon an aqueduct bridge; nor do I look upon the reason given as valid for preferring Waterstown ford to the present line; viz. because upon the present, or Mr. Omer's line, the Liffey is ten feet deep in the lowest state of the river, and at Waterstown ford only three feet deep; doubtless the case of building the bridge, simply considered, is greater at the shallow than the deep water; but as the river Liffey must have at all times a sufficient passage, and on the same width, the deeper the water the greater the section; as well as relative to the same depth, the greater the width the greater the section; the determination of the preference should rather follow from the quality of the foundation than the section of the river: at either place, rock, firm clay, or strong gravel is preferable to bog, soft clay, or sand; and if the present section is not adequate to the water that is to pass, it can at either place be made so. The weather being rainy, and the Liffey swelled so as not to admit of crossing it any where, except on bridges, prevented my making any actual examination of the foundation. An accurate section being therefore made of the valley and river, describing by borings or diggings, the qualities of soil, then the proper construction of the bridge may be ascertained, and advised upon, and it is now time to enquire into this matter, so that the same may be ascertained.

In further answer to the 5th. I observe, that the hill or rise of the Downings, where it is at present opened, is a very firm lime-stone gravel, which seems to stand very firm at an angle more elevated than 45° . And I am told that this lime-stone gravel laid upon the bog, produces an excellent meadow soil; but it is of little use for me to expatiate to you on a piece of husbandry, which I first there learned myself; however, as the whole country, where not covered with bog, seems chiefly of the same kind of gravel, it is, however intrinsically valuable, by no means so scarce as to be fetched from Downings, in preference to an easier place.

To the 6th,

I can by no means advise such deep sinkings as are here suggested; it will be found a very sufficient undertaking to get it down to the level of the Blackwood river, which

as shewn in Mr. Trail's section, appears to be the least sinking that can be dispensed with to obtain water to the canal of partition.

To the 7th.

The hill of Downings is so firm a gravel, and appears to be capable of standing so much steeper than any kind of earth, clay, or gravel soil, that I have seen before, that I look upon arching to be altogether unnecessary.

To the 8th.

Having considered the nature of the bog of Allen, with all the attention I am able, I can by no means retract what I have said in my former report, the latter part of article 8th. I do not, however, mean to be understood, that I think it a considerable degree of difficulty to form canals in bog where you can choose your level, so as never to have any extra cutting or banking of more than three or four feet.

When a person takes a ride upon the Downings, or any eminence on the border of the bog of Allen, and casts his eye upon that very extensive flat, he would not imagine any difficulty in carrying a canal over it, or in crossing it in any direction; I therefore do not wonder that when Lord Strafford first cast his penetrating eye over this bog, and perceived that it gave rise to several of your principal rivers, which run from it in different directions, he would readily form a design for their communication through this bog as their centre, and I can as readily conceive that those who have gone after him, making use of ocular inspection only, have as readily conceived, that the practicability of this scheme was exceedingly easy. This, on ocular inspection, has in general been taken for granted; it has only been by the late actual levels taken, that the difficulty has in any degree appeared: thirty or forty feet of slope, in ten or twelve miles, looks to the eye like a perfect plain; but when this comes to be reduced to a water level, it will create a terrible sinking or banking. It appears by those levels, that the middle part of the bog is the lowest of all, above thirty feet lower than the same bog at the east and west ends, while those are lower by above twenty feet than some of the intermediate parts, and are further barred up by very considerable rises that cannot be avoided; that is, by the Downings at the east end, rising no less than forty-one feet above the level of Blackwood river, and at the west end, at Knockballyboy, by an ascent of thirty-one, so that the natural drainage of this bog forming the heads of rivers, is by the middle taking their courses north and south, in a direction quite con-

trary to the desirable one of going from the east to the west. Mr. Trail has very judiciously endeavoured to avoid this difficulty upon the line first chalked out, by making two canals of partition, and thereby sinking the middle part of the canal; but still, notwithstanding those different levels, there frequently occur sinkings of the canal in the bog from eighteen to thirty-three feet deep for considerable lengths together, exclusive of the deep sinkings at the Downings and Knockballyboy, which, though I do not say they cannot be done, yet cannot be done by any method that is known to me, or that has been suggested or pointed out to me, in any given time, or subject to any given estimate of expense. It is a kind of undertaking that has, in this degree of it, never been executed, to my knowledge, or attempted. Every thing that I have done and seen in bog, even in moderate deep sinkings, has been attended with difficulty, and uncertain expenses, while, at the same time, where the level of a canal can be carried superficially upon bog, it is a thing perfectly easy.

The piece of canal that has already been attempted in the bog, by no means convinces me of the practicability of the thing; what has been done is by no means a specimen of what is to be done; it is not sunk to the depth nor width, the bottom is upon a considerable descent capable of carrying off the drainage, and has been open for that purpose several years, being begun by Mr. Omer.

The fact is, wherever I have seen it tried, that till you get four, five, or six feet deep (according to the firmness of the bog) you go on very expeditiously, and without any difficulty; but in going deeper, though the bog may be very firm at top, yet underneath retaining a great quantity of water, like a sponge, it becomes very heavy, and not readily parting with its water, the upper part begins to press out the lower, or slide itself into the cavity, and so keeps coming in as you take it out, till the whole surface is lowered to a considerable distance. The sinking a little at a time, as for instance, one spit of the spade annually, giving in the mean time leave for the water to drain off, and the adjacent bog to consolidate, is the best method I know of, and think, with much labour and patience, you may get ten or twelve feet deep. Drain the bog, say they that think it easy; true, this is a very effectual method, but then it is in this that all the difficulty consists. No drain can operate below the level of the water it contains, and by the same rule that you can make a drain of a foot wide, and keep it open, you may make a canal of fifty feet wide and keep it open to the same depth. I do not mean to limit other men's capacities, or to preclude the company from being advised by those artists who may see clearly what I do not, or whose particular experience may have led them further into the prosecution of this particular subject, than I have

I have had occasion for; but I must say, that my particular experience, so far as it has gone in this particular subject, suggests this maxim, avoid a bog if you can, but by all means possible, the going deep into it; nor will any consideration prevail, on me to pronounce that practicable, that I can foresee no adequate means of effecting, and for this reason I must answer the 8th query in the negative.

To the 9th.

From what is said in the preceding answer, it will easily be inferred, that if the carrying the canal upon different levels in the present line will be attended with extreme difficulty, and uncertain expense, the carrying it on one level will be respecting men's strength and abilities altogether impracticable.

To the 10th.

In answer to this see the 9th article of former report, in consequence of which, and of the resolution of the committee thereon, Mr. Trail and Mr. Jessop proceeded upon the level of the proposed new line from the Wood of Allen to Philipstown, of which levels Mr. Jessop made his report to me, and, as I understand that Mr. Jessop left a duplicate thereof with the company's secretary, it is unnecessary to state them here. From these levels it appears that the ground in this line is much better adapted to carry the canal of partition upon one level, than the former line upon several levels, as laid down in Mr. Trail's section; and in case more than one canal of partition is introduced, it is very immaterial into how many different levels, each descent from its respective canal of partition, is broken; because, by the known principle in artificial navigation, whatever number of locks there are in one descent, they are all worked by the same water that will work the largest; and in regard to increasing the number of locks, as they are capable of being reduced to an estimate, I think little of building a few additional locks, when put in contra-distinction to inestimable difficulties. I therefore, upon the whole, cannot avoid coming to the same conclusion upon the former part of this query as upon the 8th.

The latter part of the 10th query is answered at the end of the 8th article, to which I have only to add, that from Philipstown I see no likelihood of finding a better passage than through the high grounds of Knockballyboy, and by the Maiden and Brusna rivers.

To

To the 11th.

Of the three tracks here mentioned, having reconnoitered the country between Naas and Athy, see article 22d. now, in case I thought that a passage by the present line, through the bog of Allen, as proposed by several levels, an executable scheme, that is, a scheme attended with such a kind or degree of practicability that I would recommend the execution of it, then a branch canal from the lowest part of the main canal, between the Cuth and the Fuguile rivers, will be far the most proper, as being not only shortest, but there would be very little difference of level but what might be surmounted by one, or at most two locks between the low level of the canal and the Barrow at Portarlinton; and as there would be water coming down from both the canals of partition into this low level, they could not fail of plenty of water to work them down to the Barrow; but, as I cannot recommend this scheme, as being sufficiently executable, it will remain that the Blackwood river will be the adviseable passage to the Barrow. See article 10th, and the reasons given in the 11th, 12th, 13th, and 14th. I would not, however, recommend the passage by the Blackwood to fall into the Barrow at Monastereven, for reasons that will hereafter be given. I would recommend the canal, vessels, and locks, of the same size, as recommended in my report, articles 4th and 5th.

To the 12th.

If either the present line, or the new one traced, as per query 10th, could be recommended as executable schemes, then a branch from the canal to fall in with the Boyne near Edenderry would be best to be adopted. See article 21. But, on a contrary supposition, I should prefer the joining of the Blackwater, with the Blackwood river, for reasons that will hereafter be subjoined: its locks and boats still of the same dimensions.

To the 13th.

This being a local circumstance, I am not enabled to give a general answer.

To the 14th.

Lock houses at particular places are absolutely necessary, and every lock should have a lock house, were it not for the expense. At particular places they are necessary for
examining

examining the cargoes, and ascertaining the tolls. At particular places they are necessary for the proper regulation and distribution of the water, and at every lock they would be useful in being a check upon the boatmen and idle and evil minded persons, in improperly and wantonly spending the water and damaging the works and machinery.

To the 15th.

The dimensions of boats, locks, and canals, are amply set forth in articles 4th, 5th, and 6th, and to locks of this size less than a third of the water will be sufficient that will be necessary to work the locks, such as have been built by Mr. Omer at Clonaughless, &c.

To the 16th.

As the season was rainy when I saw the Blackwood river, I have not the means of judging of the specific quantity of water it affords in dry seasons; but for the locks, as now proposed, I apprehend the Blackwood will be sufficient to carry on a navigation to a considerable extent of business, which stock of water may be considerably increased by forming reservoirs for treasuring up the waters of the Blackwood, &c. in rainy seasons. To which end several hollows in the bog, lying above the level of the canal of partition, will be subservient, into which the flood waters of Blackwood can be introduced, dams being put across the outlets by which these hollows are naturally drained.

To the 17th.

The quantity of water that will be necessary, will, in a great measure, depend on the quantity of trade that will be carried on; it seems that the Blackwood, especially with reservoirs, will be sufficient for the first outset, and as the trade increases, the finances will also, and then additional supplies of water can be afforded to be brought at greater distances and expense. Mr. Trail informs me, that by a level actually taken, there is a fall from new bridge upon the Liffey of twenty-three feet to the canal of partition at the Downings, which, in a space of about six miles, is very sufficient to carry any quantity of water thither that can be required. On viewing the country it appears very practicable, after erecting a dam across the Liffey, a small distance below new bridge, to take water into an aqueduct on the west side of the Liffey, and passing
by

by Roseberry or Raspberry, to follow a level upon the ascent of the ground, from the Liffey toward the west, and leaving the bridge of Canah, and the mill of Cabbertealy on the right, to fall in with the canal of partition at Langonstown.—This will avoid the deep cutting that seems otherways unavoidable to come at the canal of partition by the bog of Donore; the summit or neck of that bog being proved higher than the passage by the Downings. If the Liffey's water be not necessary at the canal of partition, where it will be wanted in double quantity, that is, to distribute a lock-full each way, on the passage of each vessel, it can hardly be wanted on the Dublin side only, where with great ease the Morell river can be taken in.

To the 18th.

I look upon it as necessary to take in the Morell river, which can very conveniently be done, by an aqueduct from John's town to near Sallin's bridge, which will not only be of great assistance in supplying the partial navigation that will always obtain upon this district of the canal, but be absolutely necessary for the supplying it before it is joined by the canal of partition. From observations upon the quantity of water used by the mill at John's town, upon the Morell river, it is capable of supplying thirty-nine locks-full per day in the driest season, of such locks as have been by me proposed, supposing them to pen twelve feet difference; and if notwithstanding water should be scarce, it will be proper not to let vessels pass the large locks but in pairs, and if possible to bring together vessels going both ways; so that four vessels may pass the great locks with one lock-full of water.

To the 19th.

This is already in a great measure answered; if wanted at all, they cannot be too large. I look upon a reservoir of fifty acres capable of holding at a mean of the area six feet depth of water as a moderate size; such a reservoir will hold about forty-two locks-full upon an acre, and upon fifty acres 2100, say 2000 locks-full, which at two locks-full to a boat, and ten boats per day, will last, exclusive of leakages, 100 days, and this, or reservoirs to the amount of this, being formed in the bog itself, will be made at little expense, where the inheritance of the ground is valued at so small a price.

To the 20th.

My former report recommends article 17th, the first finishing to Sallin's bridge, which advice I am glad to find you have taken, by contracting for the works with
Mr.

Mr. Trail, upon the dimensions and depth of water advised by article 5th. The next thing I would advise to be undertaken, is the deep cutting of the neck at Downings, for the reasons specified in article 19th.

To the 21st.

I apprehend that places upon the canal for the deposition of implements and utensils are indispensable; that the company's general stores in Dublin are by no means sufficient and convenient, without others nearer to the centre of the works *pro tempore*; and yet that a place for reception, the deposition of stores, as well as for the manufacturing of some articles, will always continue necessary at Dublin: but yet I apprehend, when the canal becomes navigable for some miles from the Dublin termination westward, that the situation of the Dublin store-yard will be more proper at the canal near the city basin, than in St. James's street.—The very grounds and buildings intended for wharfs and warehouses may very properly be used as a store-yard, and store-houses, till they are wanted for their proper use, and, as said before may be added to, as occasion may require. The store-yard at Stackumney, being near the Gollerstown quarries, and central to the works between Dublin and the Liffey, I apprehend to be very properly chosen.

To the 22d.

The materials that I have seen made use of by the company are in general of the best quality; only I have thought proper to recommend the use of pozzelana for mortar, in preference to terras; the reasons for which, as well as a full answer to the query, is found in article 20th. of my former report. I will only add, that Pozzelana mortar, does not spoil like terras by becoming dry, or wet and dry, nor does it grow in the joints.

To the 23d.

This is also fully answered in article 20th.

To the 24th.

This is fully answered in the 8th. article.

To

To the 25th.

In regard to the situation of mills, bleach yards, &c. these are secondary and local considerations, about which my time and information are not sufficient; but as the company can hardly avoid making a road sufficient for a turnpike, upon at least one bank of the canal, nor can they avoid this being made a road of, it is lucky that their act enables them to erect bars, and take a toll.

To the 26th.

The water that will necessarily be brought down the canal by the passage of vessels will be far more than will supply this contract; and even if the canal were hereafter continued down to the Liffey at Dublin, the partial navigation of vessels that will deliver and load cargoes at the present termination, will, in my opinion, be fully sufficient; and for which purpose it will always be the interest of the company to continue their wharfs and warehouses there. As the Morell water appears to be fine and clear, and is said to be of the best quality, it will be proper to let no more come down from the canal of partition than necessary, and to prevent it from mixing with the Morell water, more than is absolutely unavoidable; it will be proper to fix an overfall at the west end of that stretch of the canal, where the Morell is introduced, by which means all the water coming from the canal of partition that is not necessary for the navigation of the vessels to Dublin, will be discharged before it mixes with the Morell water.

To the 27th.

Having carefully perused a paper containing the reasons for endeavouring to keep in the bog of Allen, as much as possible, rather than avoid it, I must observe, that if those reasons were valid, it would appear that an undertaking to drain and improve the bog of Allen, or certain parts thereof, would be far more lucrative than that of making a navigation from Dublin to the Shannon; for I could chalk out a far less expensive way of draining the bog, than by digging a large navigable canal through it.

As it is here stated, an acre of land is to grow from the annual value of one penny to forty shillings, without the state of one penny expense to be laid out upon it. It is said, indeed, that clay and manure may be brought by water to cover that part of the bog next the canal, at a small expense, and in very large quantities; but then the quantities necessary to cover an acre, together with the expenses of water carriage, should

should have been stated.—It is very true, that carriage from great distances in general, is cheaper far by water than by land, but for small distances it is not. Suppose that lime-stone gravel from the deep cutting at the Downings is to be had for nothing, it is yet to raise and to wheel on board a vessel; the expense of wear and tear, or hire of the vessel is to pay, and the men's wages to attend it, and horses to draw it. It is then again to be put into wheelbarrows, and run out to the mean distance of 175 yards, which alone upon great quantities will be a very considerable expense, after which I suppose it is to be spread over, and regularly disposed of. Manure may indeed be brought hither from Dublin by water far cheaper than by land; yet I suppose it is at Dublin to be paid for, to be paid for loading from different parts of the city to the canal, to be put on board, and the freight to be paid for; and though the company will reckon nothing for tolls, yet the wear and tear of their lock gates, banks, and works, in common with other vessels, will in reality be so much out of their pockets. Again, the wheeling it 175 yards, and spreading together with the proper seeds, will be a further expense; all this put together will be the purchase of an acre of land: and though I doubt not but that the land may be thus made in favourable situations to advantage, supposing the canal actually made and navigable, yet, if in making the canal navigable very great (and at present uncertain and unknown expenses) attend it, by forcing a passage through the bog, in a direction ill adapted to the same, it will be very easy to bury all the profits of the land in the extra work, upon a very few miles of this kind. It is said that the digging through the bog is far cheaper than in the firm land, not above one-third: I shall not at present dispute the disproportion, and agree, that where the bog will stand there is no cheaper digging; but if I dig out a cube yard of soil from the firm land it is done, but under an idea of digging out a cube yard of bog, I have to dig out that and nine others, that will follow it, before I can make good the yard I want, I apprehend the balance will be on the other side of the book.

The query states, whether it will or will not be much for the advantage of the company, to carry the line as far through it as can be done with propriety? I apprehend it may; but the question turns on this, where it can be done with propriety, and from what is here stated, and from what has been already said in answer to query 8th, it is very plain that it will on no account be to the company's advantage to go through the bog, where it will require deep cutting; and to fix some idea to this term, I mean where it will exceed ten feet deep: yet this greatly differs according to the natural texture and firmness of the bog; my answer therefore is, that where the company have their choice, in going through the bog of Allen, or not, without deep cutting

or high banking, I apprehend it may be for their advantage, and, consequently, for the national advantage; but I can by no means advise the company to attempt to carry the canal through every thing that may oppose in the bog of Allen, merely for the sake of gaining and improving ground. For, at any rate, it does not seem that a navigation can be carried on from Dublin to the Shannon, without going through so much of the bog of Allen, as will afford ample opportunities of trying those experiments.

ADDITIONAL CONSIDERATIONS.

Having now dispatched what occurs to me in answer to the several queries, in order as they stand, I beg leave to add such further matters as have presented themselves to me since my former report, which could not so directly be given in answer to the queries.

In my former report, article 10th, I have strongly advised the company first to complete a navigation to the Barrow, before they begin to work from the Togher of Graig, towards the Shannon, for reasons given in the 11th, 12th, 13th, and 14th articles, which advice I now repeat; and, besides those reasons, I beg leave to add the following one, that I am now fully convinced, that this is the only executable and adviseable road to the Shannon, and by which means not only the junction of the Shannon and the Barrow with the Grand Canal, will be united in one interest, but also produce the most direct communication of the Barrow and the Shannon.

From what has been already stated, in answer to the eighth, ninth, and tenth queries, it does not appear likely, that any executable and adviseable scheme can be formed to obtain a direct passage from the Togher of Graig to Philipstown, upon one level, nor indeed without extreme difficulty upon any number of levels. If, therefore, at any rate, we must adopt at least two canals of partition, it will be more eligible to do it in such a way as to draw every possible use from this construction. It has been already stated, report, article 10th, that the junction of the Barrow with the canal, by means of the Blackwood river, will be perfectly easy, and in point of probable profit adviseable prior to, and, independently of all the rest; suppose then, after the meeting of the canal with the Blackwood river, which I will call the fixed point, we carry the canal down the declining valley of the Blackwood by Rathengan, as has been already proposed; but, instead of inclining it towards Monastereven, it be inclined towards the joining of the Blackwood, with the united stream made by the Cush and Figuile rivers, which will be upon

upon ground very little elevated above the Barrow, at Portarlinton, it being overflowed to a great distance when I saw it; so far then we may lay it down at all adventures expedient for joining the Barrow, and taking in a navigation from Portarlinton, as well as from Monastereven, the best adapted possible. This course, from the fixed point to junction with the Figuile, will be, I suppose, about nine miles, from thence to the Barrow about two, but ascending from the said point of junction of the Blackwood and Figuile, by the gentle inclined valley of the Figuile, we shall, in a course of about eleven miles, come to Philipstown bridge, so that this will be a stretch of twenty miles from the fixed point to Philipstown bridge. According to the present line, through the middle of the bog, it is fifteen, so that when you are arrived at the joining of the Blackwood and Figuile, you are then four miles nearer Philipstown by the course of the Figuile, than at the fixed point in crossing the bog according to the present line. According to Mr. Trail's plan of the branch canal to the Barrow at Portarlinton, which is the shortest communication of all, it is nearly seven miles; therefore, Philipstown bridge and the Barrow, taken conjunctly, in either case, are joined with the fixed point by twenty-two miles of canal. It is true that the course from the fixed point, by the Blackwood and Figuile to Philipstown, in a passage to the Shannon, being twenty miles, is five miles more than according to the present line, which is only fifteen; but then, as I apprehend, no proportion of distance subsists between a practicable and an impracticable passage. The ineligibility, not to say absolute impracticability, of any passage from the fixed point to Philipstown across the bog, has been sufficiently pointed out; what renders the now proposed line a practicable and an executable scheme, is, that while you are following the valleys of gentle declining rivers, you are sure the general surface is inclining one way, and gradually either rising or falling, according to the course you are going; so that if in bog you can always choose your ground, and by making locks at proper places, can always avoid deep cutting and banking, for at any rate you can take the trough of the river for your canal; and it happens very luckily here, that rivers run upon so flat a bed, that according to the levels taken there should not be above nine or ten feet difference between the levels of the united streams of the Blackwood and Figuile, and at the crossing of the branches of these rivers separately in the bog; so that I compute there will not be required above one lock more in completing the junction of the Shannon and Barrow, taken together, than would be required according to Mr. Trail's section.

In taking the distances above mentioned, I have measured them by the course of the rivers, not indeed according to their smaller meanderings, but their general direction as their borders are mostly flat; but when this scheme comes to be surveyed by the level,

level, it is very probable that the courses may be shortened, without encountering any deep cuttings and high bankings; and particularly that the canal may be taken round, so as to effect a junction of the Blackwood and Figuile, by a nearer course than by their natural junction.

Respecting the passage of the Downings, I by no means look upon it as a very formidable obstacle in so great and expensive an undertaking. The soil is near upon the most favourable of all for such a purpose, and which having reduced to calculation, in my opinion, may be done for the sum of £13,500 extra to the expense of the same length of plain canal. In fact, I look upon the deep cutting at Knockballyboy to be the more formidable work of the two, on account of the uncertainty of the deep cutting in bog, no less than thirty-one feet deep; however, as the ascent is steep, and, consequently, the bog very much upon the decline, it is naturally firm and dry, and as the ease of tapping the under parts is proportionable, I hope, as all the difficulty after passing the Downings will be reduced to this one, that it will not be found insurmountable, yet still if possible, it will be well to avoid this also; and though, from the views I have had, I have seen no probability of avoiding this passage, if the canal goes by or near Philipstown, as I have reported in answer to the latter part of the tenth query, yet, as at the time of making this view, I had no idea of taking Rathengan in the course from Dublin to the Shannon, I did not reconnoitre what might be done in effecting a direct junction between the rivers Barrow and the Shannon, but now remembering that the country was pretty flat in travelling from Banagher to Portarlinton, and observing that the Barrow, (which runs upon a dead course for several miles above Portarlinton), together with its branches, form near approaches to the head of the Maiden or Tullimore river, to Lough Pallas, whose waters fall into the Maiden, and to Lough Haunch, whose waters fall into the Lower Brusna, and by a pretty direct course by Birr to the Shannon, observing also that Mr. Trail, in his report, has mentioned an information of a passage by Lough Pallas; it is possible, that though such a passage may not be eligible from the bog of Allen, yet it may be so from the Barrow; I say, taking all these considerations together, it seems well worth the company's while to order the part of the country now pointed out to be reconnoitred; and if any passage seems more favourable than that at Knockballyboy, to have a particular survey, level, and section taken; and in case the company approve of this proposition, either by way of the Figuile and Knockballyboy, or any passage from the Barrow that may be more favourable, it will also be proper to have a survey, level, and section, taken of all the parts which have not been already reduced to paper, and then I have not the least doubt but that the whole work, the bog cutting at Knockballyboy, (or something that may occur of the same kind in making good
any

any other passage at the western summit), excepted, may be reduced to a fair and grounded estimate, so that the company may see what they have in reality to do, in order to effect this great and very desirable work.

According to this construction, as well as that proposed by Mr. Trail, another collection of water will be necessary to supply the western canal of partition, but as the eastern will have the united trade between Dublin and the Barrow to Lock as well as that of the Shannon, and the western will have that of the Shannon only, with possibly a small trade between the Shannon and Barrow, it is possible that much less water will be wanted at the western summit than the eastern, and to this end the head of the Figuile river above Philipstown will conduce, which, as I observe, turns a mile near Philipstown; this, probably, with proper reservoirs, will be sufficient, yet it will be advisable, (if this at last is found the most favourable passage), to reconnoitre the country, to see whether the head of the Tullimore river, the head of the Esler, or the water from Lough Pallas, or any other, cannot be conducted by aqueducts to the western canal of partition.

After the junction is made with the Figuile from the Blackwood, (supposing the Figuile the most eligible passage), and the navigation effected from thence to the Barrow, at some convenient point between Portarlinton and Monastereven, the company will then be in possession of the Barrow trade. For as there is already subsisting a sort of navigation from Portarlinton to the bridge of Athy, by openings made in the mill weirs for that purpose, and though this kind of navigation is very imperfect, yet it may, with some improvements, for a time be sufficient for the trade, or as the mode of making a navigation from Portarlinton to the bridge of Athy is no way difficult or expensive, the company will have it in their power, if they find it expedient, to perfect this branch at once, and at the same time proceed from the aforesaid point of junction with the Figuile for the Shannon.

As, according to the now proposed plan, the canal is to be carried no further in a direct line into the bog of Allen, than the meeting of the Blackwood river, it seems that the method of joining the Boyne, by means of the Blackwater river, according to the scheme proposed by Major Valency, will best suit the ground by which a direct passage from the Barrow to the Boyne will be formed by means of the Blackwood and Blackwater rivers, united near the Togher of Graig in the bog of Allen.

J. SMEATON.

Austhorpe, 3d April, 1775.

TYRONE

TYRONE CANAL.

Mr. SMEATON's opinion on Mr. JESSOP's REPORT on the Tyrone Canal.

To Mr. JESSOP,

Dear Sir,

Brough, 30th April, 1774.

MY journey into Yorkshire gave me an opportunity of reading and considering your report, by way of representation of the several matters relative to the works of the Tyrone canal; and having been at home but one day, I now take the opportunity of a leisure hour to give you my opinion thereupon, so far as I can do it without entering into calculation.

Had this canal been unbegun, the circumstances attending it are such, that I never could have recommended a canal of any kind, as I am sensible it never could be made in any degree to answer the expence: but if I understand you right, the bulk and expence of the work is in a great measure incurred, there being little to do but to complete the inclined planes between the different reaches of the canal. I think, therefore, that it would be a great pity after the public has been at so considerable an expence in constructing the apparatus, but that the experiment was made, and the validity of this mode of navigation put to a thorough proof, especially as it may be a moot point, whether it may be cheaper to navigate upon this canal, supposing it ready made, and given for nothing, or to begin a new work, which, at any rate, will cost a considerable sum; for by this means the public will at least be put into possession of this piece of knowledge, i. e. how far a scheme of this nature is likely to answer in other places.

I think the best chance of its succeeding will be by obliging the loaded boats going down to draw up the empty ones returning, which may be done by a simple pulley, with a brake or convoy upon it, to moderate the velocity of the descending boat, and that a great deal of friction may not be wanted upon the pulley, as you say the plane rises one in five, I fancy they will act very sufficiently, if they are made to slide upon the solid, rather than upon rollers; but I fancy that light wooden rollers will be wanted at proper distances to keep the ropes from rubbing upon the gravel or solids between the slides; and as I do not apprehend that above one boat can be let down at a time, for greater dispatch I think it will be better to make the boats carry two tons rather than one, by making them of double length. I do not, however, hint these things by way of adopting the scheme, nor can I answer whether it will do or not; but as matters are carried on to so great a length, by way of suggesting the likeliest means of getting an effectual trial of Mr. Dukart's scheme.

If

If his scheme does not on trial answer, I am of opinion, that a rail road of wood, in the manner of those at Newcastle and Whitehaven, is much to be preferred in such a situation to either a canal or a gravelly road, especially as you say it can be done with a length of two miles, and all or most of the way downhill: this being the case, the waggons will go down loaded by their own gravity, and the horses will have nothing to do but to draw them empty back again, which, in a rise of 192 feet in two miles, will be easy work.

Rail roads of this kind are in common situations executed in the neighbourhood of Newcastle, so as to carry coals at the rate of 2*d.* per neat ton per mile, the original charge of making, maintenance, of wear and tear of the roads, waggons, horses, and drivers included. But as the cheapness of things greatly depends upon a country's being used to the execution, which can never be the case in the first instances, if we suppose 6*d.* per ton per mile, of the Tyrone tons, they will be no more than 1*s.* per ton for the two miles, and in all probability will be cheaper than it can be done upon the canal after the whole of the original expense has been given.

You will be pleased to communicate my sentiments to my Lord Archbishop of Armagh, with my most dutiful respects, and am,

Sir,

Your most humble servant,

J. SMEATON.

P. S. I apprehend it will be necessary, besides a simple pulley for returning the rope, to have something of a tackle, assisted by a winch or windlass, by way of bringing the boats upon the inclined plane, and till they are launched upon the down-going side.

DRAINAGE

DRAINAGE of NORTH LEVEL FENS.

The REPORT of JOHN SMEATON, engineer, concerning the drainage of the north level of the fens, and the outfall of the Wisbeach river.

AS I perceive that much has been said and wrote upon the subject of the great level of the fens, and that a variety of opinions has been entertained concerning them, I find it necessary, in order to clear my way, to deduce what I may have to offer upon the subject of the north level, from its original, and though I set out with an hypothesis, which may be granted me or not, yet, as it is to be considered in no other light than a means of introducing certain matters of fact, which being in themselves incontestible, what is founded thereon will be equally true, whether the supposition by which they are introduced, be so or not.

I suppose then, that there has been a time when the whole of the great level of the fens, together with the adjacent low countries, has been one great open bay, where the tides have freely flowed and reflowed: I suppose also, that for a long course of years, far beyond what any present accounts of this matter reach to, a cause has subsisted, by which a quantity of sand and earthy matter has, by the action of the winds and tides, been gradually brought upon this part of the coast, and has particularly lodged itself in this great bay, as a receptacle where it could lie at rest: this being granted, it would follow that this bay would gradually become more and more shallow, till the matter deposited from time to time should become higher than the rise of the neap tides, in which case a country would be formed, and would grow over with grass, and form what we now call salt marshes: but as the waters of the upland country must continue to have a passage to sea, which had their outfall into this bay, they, conspiring with the flux and reflux of the tides to cover and uncover the surface of the land, must, while the very land is forming, make the channels necessary for the discharge of the land waters into prodigious large and deep gullies, whose bottoms we may suppose far deeper than the low-water mark at sea; and which, as soon as grass was formed upon the level surfaces near their borders, would put on the appearance of rivers. This being the case, the inhabitants would gradually observe, that by raising very inconsiderable banks against the rivers, to shut out the spring tides, the land might be gained from the sea; and, admitting the inhabitants of that age to have the same natural sagacity that we have, we cannot suppose they would find

find it difficult to contrive expedients to let off the downfall and soakage waters into the opposite rivers, when the tide had retreated, by means of some kind of tunnels laid through the banks, equivalent to our small stop sluices, which would be the whole of the art of drainage the country, in this condition, would want. By these means, a very great tract of country would be gained in a little time, which being immensely fertile, inhabitants would of course flock hither, and multiply apace; villages and towns would be built (as in the most eligible situation in a flat country) on every little eminence or rise of the surface, originally produced by some storm or tempest, that had thrown up and amassed a greater quantity of matter in those places than in others.

It is evident, that, after the tides were shut out from flowing over the surface of the lands, the quantity of flux and reflux of sea-water at each tide being greatly lessened, and in consequence of its velocity, the power of scouring would be thereby weakened; the channel of the rivers would therefore silt and contract from the very same cause by which the country itself was originally formed: but, as those rivers would, as already stated, be very large and very deep before the imbankation, and as they would still contain a large quantity of salt-water flowing and reflowing, and thereby still exert a very considerable power of scouring; it would be a course of years before the rivers would become contracted in any considerable degree: and this contraction, though we may suppose it apparent enough, in the compass of one age, yet making its appearance at first more in width than in depth; and as thereby a quantity of land would be further gained from the rivers, it would be far from being viewed in an unfavourable light, and the rivers being still supposed to be so deep as to ebb every tide far below the surface of the land; as mankind could not then be supposed to be furnished with the experience of after ages, or to see the result of nature's tendency, the gradual changes that they might from time to time perceive, would not prevent them from supposing, that things would always continue in the same flourishing state: and, in consequence, costly churches, abbeys, and monasteries, would be built, and great ecclesiastical establishments made, in so fertile a country.

So far we have proceeded by manifest deductions from two assumed positions, viz. that the whole level was originally sea; and that nature has been gradually making an addition of matter to this coast.

That the latter is and has been the case in our own times, and as far back as any accounts of history reach, is very certain: we may therefore infer that the same process

has taken place, in times antecedent to the written accounts, and for a time backward, to which we need not prescribe limits: this being the case, the first assumption must be presumed, as the most natural state from which the effects of the second could proceed or be manifested.

The flourishing state of the fen country, as above described, is sufficiently testified in history; now, if it shall appear that the levels of the present surface of the fens are such, with respect to the present low-water mark at sea, that upon a supposition of large and deep rivers, the fens would naturally be in that flourishing state by the simple means of drainage before described, we may infer, that there actually were then those large and deep rivers: and if large and deep rivers, in a country where there are not powers sufficient to maintain them such, are the natural consequences of a country arising out of the sea, we may then fairly infer, that the country had its origin that way: and if, from the same causes still acting, this same flourishing country becomes a drowned and desolate country, as we are most sure it has been, we may conclude that the whole mutation has proceeded from one regular process of nature, gradually operating, and not from any unusual convulsions of her frame, nor from the superior skill or industry of former ages, nor from the particular neglects of those who succeeded them; and hence we may conclude, that we are not to expect to recover this drowned and desolate country, by partially restoring things to the same situation as they were in, when in that good state; for without we could restore the whole, and at the same time put a stop to nature's process, the same causes, still producing the same effects, would again reduce us to the same deplorable condition: we must therefore rather look out for such artificial remedies, as shall from time to time countervail nature's gradual process, so far as it is in our disfavour.

That the general surface of the fens is sufficiently high to drain, in the easy and natural way above described, upon the supposition of a large and deep river, is hence apparent. According to the levels and section of the river that have been taken by Mr. Elstobb, the bottom of the river Nene at Peterborough bridge, is now somewhat below the level of the sea apron of Gunthorpe sluice; but a little above the low-water mark at Sutton's washway house: it appears also that the low-water mark at the washway house, is near six feet above the low-water mark at the Eye, or road where the ships lie, and which is supposed to be the same as the low-water mark at sea: it appears also, that the surface of the lands in Wisbeach high fen, near Narr lake, which are supposed the lowest in the north level, are eleven feet and a half above low-water at sea, and the surface of the lands near Jacklin's house, opposite Thorney lordship, is
thirteen

thirteen feet above the level of the sea. Now, when the river Nene ran in a large and deep channel, and before the general outfall, called the Metuaris *Æstuarium*, was choaked with sands, as at present, we may suppose that the level of low-water at the river's end, was then the same as the low water at sea; and as we also may very well suppose that the channel of the river might, in general, be ten feet deeper than low-water at sea, in this case it would ebb out so much, even at a great distance from the outfall, as to want but a very inconsiderable declivity per mile to sea at low water. The fall therefore from the lowest lands in Wisbeach high fen to the river's end, would be eleven feet and a half, the same as it is now, to the upper beacon at the Eye; a difference in extent of ten miles according to the low-water channel; and supposing the water in the drains to have stood two feet below the general surface of the lowest lands, there would still have remained nine feet fall at a spring tide low water; and supposing the ebb of a neap tide to be nearly as now, viz. four feet less, there would have yet been left five feet and a half fall from the surface of the drains to low-water. The surface of the lands mentioned, near Thorney lordship, being stated to be thirteen feet above the level of low-water, would have a greater fall in all cases than the other, by one foot and a half, but being farther distant from the river's mouth, would have no preference in point of drainage; but having full eight feet for the declivity of the river's surface, even at neap tides, this is sufficient to carry it with a brisk current, in such a channel as we suppose, at three inches per mile, to a distance of thirty-two miles to sea: and I doubt not, but that in those days, the surface of the water at low-water at Peterborough bridge, ran as low as the present bottom; and that the bottom then was considerably deeper than at present, being now filled with land mud.

It is true, that the supposition of so large a channel, would bring a much greater influx of tide into the country; for it appears that the high spring tides flow at sea higher, by near five feet, and the ordinary spring tides above one foot higher than the ordinary surface of the water at Peterborough bridge, as it was when the level was taken; yet, by the same rule, that the water requires a declivity to seaward at low-water, on account of distance, it would require a declivity to landward on tide of flood; that is, distance requiring time, it would be considerably ebbcd at the river's mouth, before it would be high-water at a distance up the river; we may therefore suppose, that according to the curved course in which it appears the river Nen anciently ran, the spring tides would never rise so high at Peterborough, by full six feet, as the sea level, and the neap tides be but barely sensible. That this would be the case, appears from present experience; for the spring tides, though in a shorter, but more obstructed course, seldom flow higher than Knarr lake, where the surface is lower by almost one foot

foot than at Peterborough bridge, and by two feet than the ordinary, and by five feet and a half than the extraordinary, spring tides. Now, as the ordinary tides never could rise at Peterborough so high, by several feet, as the present ordinary surface of the water there, and as the land flood waters seldom rise in the open tides-way of a large river much higher than the tides themselves, it will follow, that the country about Peterborough might be an unimbanked country, and that very moderate banks would be a defence against every thing lower down, the neap tides scarcely rising higher than the surface of the lands.

According to this state of the rivers and tides, we may suppose those level countries to have continued very flourishing for many years; but as there does not appear to be a quantity of land water flowing through them, capable of maintaining the channels of the rivers so large and deep, as is necessary for their perfect drainage, upon the easy and simple principles already described, the sand gradually accumulating upon the coast, and thereby choaking up their mouths, and removing the point of low-water to a greater distance, would gradually check the reflow of the tides; the channel of the rivers would therefore by degrees contract, both in width and depth, till they would with difficulty convey the land floods with sufficient speed to sea; and in consequence, breaking their banks, and overflowing the country, first in a less, then in a greater degree, and more and more frequently, till the inhabitants becoming greatly annoyed thereby, and their crops destroyed, even before the drainage was totally spoiled, would, on finding lesser expedients insufficient, apply themselves to greater. The great land floods would therefore naturally be regarded as the most formidable enemy; and the inhabitants being ignorant of the consequences, which the experience of after-ages has furnished the knowledge of, how to get rid of them would be the first and principal question: and if there appeared a practicability of turning them in other channels, where they might spread and become dissipated, this expedient would of course be eagerly embraced, in preference to that of raising the banks of the river, in order to confine them and force them to sea; by this means, having lost the operation of that great and powerful engine of nature, towards scouring and keeping open of rivers, viz. the great land floods, the river would then begin to silt at a great rate, and thereby, the bottom becoming so high as to spoil the drainage, ruin and destruction would come upon the level in a manner at once; and the inhabitants and land-owners being totally unprepared to unite in one general scheme for their relief, things must in a small course of years, come from bad to worse, so as to bring this fertile country into the deplorable condition it has been represented: and so it must by nature continue till fresh combinations

binations of men could be formed, with fresh spirits, and fresh purses, in order to set about these works which were likely to give a general relief.

Something seems to have been attempted very early, to remedy those evils, by cutting new leams and channels for the rivers, in order to give them a shorter passage to sea, and thereby to gain descent for the drainage of the lands; but as they seem never to have sufficiently understood, or attended to, the point of confining the land floods, and keeping them as much as possible in a body, in order to scour and keep open the outfall, instead of dissipating them by different channels, all their schemes became abortive by the outfalls growing so much worse, while the new leams were cutting, that by such time as the work was completed, or soon after, they found themselves in as bad a condition as when they begun.

Having endeavoured to account for and establish the reason for the ancient flourishing state of the fens, and the causes of their succeeding destruction, let us now take a view of what has been principally done by the undertakers for regaining them.

The original of the modern projectors in draining came out of Holland; and their established maxims seem to have been to imbank the rivers, so as to prevent the land floods and high tides from overflowing the lands to be drained, but to leave the rivers open to the free action of the tides: then to conduct the downfall and soakage waters of the country to be drained by a sewer to some place at or near the low-water mark at sea, that the waters of the country might run off at low water, by a natural descent, and to place sluice doors at or near the mouth or outfall of the said sewer, so as to prevent the tides water from reverting: also, in cases where it is found or thought expedient, to make new channels or courses for the rivers, in order, by diminishing their distance, to increase their proportional fall.

Upon this idea (which is very complete when it happens to take in all the circumstances) the modern works of the north level, under consideration, seem to have been carried on. With a view to shorten the course of the river, I suppose originally Morton's leam, and afterwards the new leam, have been cut, and the matter thence arising employed to form banks to prevent the land waters from overflowing the level. In order to receive and carry to sea the drainage waters from the south Eau, and other drains intersecting the country, the Shire drain has been cut, or enlarged, and adapted to that end: upon this sewer a sea sluice, now called Hill's sluice, was put down in the 1637, by King Charles I. then at the head of an undertaking for the drainage of these levels;

levels; all which works seem tolerably well designed to answer the end, at the time they were put in execution; and I doubt not would have answered the end very well, if nature would but have lain still and been quiet, and left things in the state in which those undertakers found them; but the misfortune is, nature has still also been busily carrying on her work, of making addition to the sea-coast; so that Hill's sluice, which, at the time of its erection, must be presumed, was sufficiently near the tides way to have answered the end proposed, viz. of a sea sluice, by degrees got so remote from the main channel, that the outfall being found too liable to silt and choak, by the sands deposited therein by the tides, another sluice was obliged to be built nearer the tides way, called Gunthorpe sluice, which also, in time, proving not sufficiently effectual, another sluice, bearing the same name, was built not many years ago still nearer the sea; but this sluice, like the former, by the gradual progress and working of nature, has lost its due effect; for when I was there in September, 1767, I found, when the tide was out, and the land doors shut, that there remained five feet four inches dead water, upon the sea apron; whereas, to produce its due effect, Gunthorpe sluice ought to run at two feet five inches water, upon its sea apron: it is said, indeed, that before the last spring tides, it ran at three feet ten inches, but then the bottom was too high, by one foot five inches, to produce a sufficient drainage: and even the uncertainty is a great detriment; for if after the top waters are run off, a spring tide comes, and lands up the outfall, the drainage may be lost for a season.

When the new sluice of Gunthorpe was built, the old one was demolished; but Hill's sluice is yet maintained in repair; the purport being to hold up a quantity of tides water, to be taken occasionally into the drain between the two sluices, as a reservoir; and therefrom at low water, to discharge the same, by means of the draw doors at Gunthorpe, to scour out the outfall channel between that sluice and the main channel of the river. This disposition has been well intended, and, supposing no other way practicable, would have been a very commendable expedient; but as it appears that there has been, in all modern times, a sufficient depth and certainty of channel, and ebb of tides, at Sutton's washway house, to drain the whole level, it is a great pity, that when Hill's sluice was found ineffectual, and a new sluice must be erected, that it was not immediately carried down to the washway house: and it seems next to infatuation, that when the first sluice built at Gunthorpe was rendered ineffectual, and to be taken down and removed, that it was not then carried to the lower place. However that might be, it is certain that the further increase of matter thrown up, and left by the tides, produce still the same effect of choaking the outfall channel; and that the operation of the reservoir has not been able to keep it open and free.

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The reason of which, as I apprehend, has been, that finding the large tides taken into this reservoir, to have deposited so much silt as to endanger the choaking of it as a drain, it has occasioned that this matter has not been steadily, thoroughly, and sufficiently tried; for though by taking in the moderate tides only, to prevent sediment, and those but now and then, the effect has been found inadequate, and a quantity of silt gathered in the reservoir; yet, had the greatest tides been taken in, and that sufficiently often, so as to clear the outfall channel down to low-water mark at the washway house, the water held up in the drain beyond Hill's sluice, would then have so much fall in passing through the reservoir, as to produce an effect, in scouring it from the silt left by these great tides: whereas, I can readily conceive, that the taking in the middling tides only, and those in such degree as to fall far short of a thorough deepening of the out channel, would be attended with a bad effect, and thereby discourage the further prosecution of the experiment: but were the use of the reservoir prosecuted with vigour and judgment, and hedgehogs used, to assist the waters in scouring both the outfall channel and the reservoir, it seems to me that great assistance might be derived from these operations.

In case the use of the reservoir were to be set seriously about, it is quite necessary to place the land doors upon the land side of the sluice; for, being placed on the sea side of the sluice, along with the sea doors, they have not sufficient firmness to resist the pen of the great tides left in the reservoir, without danger of derangements: it appears also proper, that, to procure scours for the reservoir at times when the land waters of the drain are not of a sufficient height, it would be proper to put down a staunch, or slight stop sluice, somewhere about Tretham bridge, in order to take in a body of water, to be held up between the staunch and Hill's sluice, for scouring the reservoir when a sufficient fall is obtained by deepening the outfall channel to seaward: this body of water may be taken in from the small tides, when they are clear, and consequently little or no silt will be deposited from them: and those secondary scours should always be made as soon as may be, after the great tides have been used for scouring the outfall, that the silt deposited may not acquire a degree of firmness by lying.

These methods, in whatever degree they might succeed, it is very evident, will require to be incessantly repeated; and that from the constant addition of matter to the coast, they will every year become less and less effectual; yet, considered as temporary expedients, to preserve the level in a tolerable state till something more effectual can be done, they may have their use, and be deserving of further trial: but as it appears

to me, that no effectual method can be taken of confining the channel of the river among the broad and loose sands, so as to keep close to the Lincolnshire coast (as I am informed it has sometimes done) and thereby to afford the Gunthorpe waters a short outfall channel; nor of preserving the outfall channel from silting, and its bottom frequently getting higher between the sluice and low-water mark, than is consistent with the good drainage of the level; it follows, that the only safe, certain, and lasting way of procuring a good outfall, will be at once to prolong the drain, and build a new sluice as near as possible to, but above the washway house. At this place alone, all accounts agree, that the main channel of the river has been constant, or with very little variation, for a long course of years. The channel here runs the nearest the shore, of consequence the outfall channel of the sluice will be short, and, if obstructed, will be the most readily cleared, whether recourse be had to nature or art. The ebb of the water here is also sufficient to make a complete drainage of the level, which appears as follows.

The waters of the drains having been rendered stagnant for some days, by shutting the land doors of Gunthorpe and Clow's cross sluices, and the weather being calm when I was there, I found that the top of the threshold of Clow's cross sluice lies two feet one inch higher than the sea apron of Gunthorpe sluice; and the sea apron of Gunthorpe sluice, according to Mr. Elstobb's levels, being nine inches higher than low-water mark at washway house, it follows that the threshold of Clow's cross sluice is two feet ten inches higher than low-water mark at Sutton's washway house.

It has been observed by Mr. Wing, of Thorney Abbey, whose business it has been to observe and to know the state of this level, that when there is four feet water upon Clow's cross sluice, then the general surface of the north level is in a state of drowning; and it has been remarked by the reverend Mr. Dickinson, of Wisbeach, who has been curious in observing the state and condition of the neighbouring levels, that when there is from two feet to two and a half feet water upon Clow's cross sluice, then the lowest lands in the north level, west of south Eau bank, which is Wisbeach high fen, begin to be under water. These observations nearly agree with Mr. Elstobb's levels, who makes the land there somewhat higher; but as the observations are of a nature from which the general surface can be judged of, better than by levels taken with instruments, I shall found myself thereupon.

Taking therefore the medium, viz. two feet three inches water upon Clow's cross sluice, to be even with the surface of the lowest lands in the north level, we shall have
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the surface to be five feet one inch above low-water mark; and supposing the surface of the water in the drains to be reduced two feet below the general surface of the lowest lands, in order to make a complete drainage, we shall have remaining three feet one inch of fall from Clow's cross to the washway house; which being a distance, by the course of Shire drain, of somewhat more than twelve miles, will allow a fall of three inches per mile; a quantity not only sufficient to run off the water, but to vent the downfall waters with so much speed (upon a supposition that the drains, sluices, and bridges are made answerable) that this level may once again emulate its ancient state of fertility.

This point being established, I trouble not myself with computation, as to the lands betwixt Wisbeach fens and Peterborough, because the general rise of the country that way, will countervail the greater distance from the outfall: nor with the drains that are necessary to be made or opened, in order to give passage for the water through the level from west to east; not doubting, but that if the waters are reduced at Clow's cross, nearly even with the present threshold of the sluice, the country wants neither skill nor industry to conduct them thither.

It has been commonly observed, that Lutton's leam is the best outfall of the whole country; and it has been made a question, whether it would not be best of all to carry out the north level waters by way of Lutton's leam. It is certain, that the outfall channel of Lutton's leam falls into the main channel, near to the Eye, that is, at or near to low water at sea, and therefore has the greatest advantage of descent: but it is equally certain, that the coast is here advancing into the sea very fast; that Lutton's leam sluice is now nearly two miles from the main channel; and that, out of this distance, the leam makes its way over broad sands, a mile and a quarter; in consequence whereof the outfall channel of that leam is so far choaked, that though the apron of the sluice lies two feet two inches higher than that of Gunthorpe, yet, as it never runs lower than about fourteen inches water upon that apron, it will follow, that the outfall channel of that leam is not better than that of Gunthorpe, than by about one foot: it is true that an addition of water will mend it; but then we cannot tell how much. For these reasons I am of opinion, that an outfall at Lutton's leam, will be greatly inferior to an outfall at Sutton's washway house. It has also been queried, whether an outfall at Westmeer creek might not be preferable to the washway house, as being nearer the low-water at sea; but it appears from the levels, that the low-water mark in the channel opposite Westmeer creek, is not above one foot lower than that at the washway house; and as the main channel is now departed from the shore, to above a

mile distance, I do not think the channel, or gulley, that is commonly found near the shore, sufficiently to be depended upon, for an outfall to the north level; and for these reasons think an outfall at Westmeer creek far less eligible than at Sutton's washway house.

It may naturally be asked me, whether, from my own position of a gradual increase of the sea shore, the outfall at Sutton's washway house may not, in time, come to be choaked up; and consequently, whether it may not be preferable to go to Westmeer creek, or Lutton's leam, as getting at a greater distance from the enemy? I answer, that so long as the upland waters maintain their course to sea this way, according to present appearances, there seems a probability, that an effectual outfall will be maintained, for a greater course of years, at Sutton's washway house, than at either of the places above mentioned; which I expect to make appear more demonstrably, when I have treated upon the river, which now comes in course to be considered.

In drainage it is not only necessary to procure a good outfall, but to defend the lands from being overflowed, by the foreign waters coming down from the upland country; in short, to maintain a good barrier. According to the Dutch maxim, imbank the rivers very well; but after the rivers have been imbanked, the reflow not being able to carry out the sands brought in by the tides, the river's bottom becomes raised, till in many places it is higher than the surface of the land to be drained; in short, till it is so choaked, that the great land floods, instead of finding their way to sea with a good current, and thereby clearing out the sands brought in by the tides, when the land waters are weak, they overflow and break the banks, and drown the country, which again tends to increase the evil, as thereby their use in scouring is lost: things brought into this situation, what is then to be done? The most obvious and (as it would seem) natural means are, to dike out or otherwise deepen the river, agreeably to its former state, or to raise the banks in proportion, so as to be able to confine the land floods, and force them to sea, which will of consequence deepen the river; and, at the same time, to take all means to increase the reflow, so as to prevent, as much as possible, the sands from returning: this looks very well upon paper; but as to raising the banks, that, it seems, has already been done till, in many places, from their weight, and the softness of the ground they stand upon, they subside upon being raised higher; and from the great weight of water constantly upon them, and sapping their foundations, they become liable to breaches, when the extra-weight of flood waters comes against them. It is true, that speaking theoretically, banks may be made of so large a base, as to bear being
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carried up to the necessary height and strength, upon any kind of substance that can be called ground; but in fact, where a want of matter is the natural defect of the country, the charge of amassing together so much matter as would be fully equal to this purpose, would be so enormous, that the proposition must die in the idea: besides, even supposing such banks made, which would, in consequence, deepen the river, yet, as nature still keeps at work in lengthening the course of the land waters to sea, the declivity would, in time, become so much lessened, that the sands would once again increase upon the power of the reflow; and the banks that now are sufficient, would, in a course of years, become insufficient; so that the banks would need raising higher and higher without limitation.

In regard to the diking out the river, this, if done so as to make a small channel, the same causes still producing the same effects, will soon be landed up again; and to make a great channel, such as I have supposed in the flourishing state of the fens, would not only be an enormous expense, but if made, as the ordinary quantity of land waters is not sufficient, and the land floods not sufficiently frequent to maintain such a channel, it must by degrees fill up again, as it has done before: and though a large channel, from the superior action of the tides, must fill slower than a small one, yet, if it could not maintain itself when the general outfall was less obstructed with sands, it cannot be expected to do so when more obstructed: nor, indeed, can I apprehend it practicable to perform any material deepenings of the river in its present channel: for if the water were diverted from the river to another outfall, while the work was doing, in all probability, for want thereof, the outfall would be entirely landed up and lost.

I do not apprehend, that any great matters can be effected in deepening the channel by any other means than men's hands; for though all attempts to help the natural scour by hedgehogs, &c. are very laudable, as they tend to prevent bad from growing worse, yet, to perform any great matters this way is not only attended with great labour, but that labour must be continually repeated, in order to maintain the improvement before gained.

When the rivers Ouse and Welland went out at this outfall, as well as the Nen, here was a considerable power to contend with the sands; but the two first sources being (I suppose) for ever lost, no improvement, in point of quantity, offers itself, save the unnecessary diversion of the waters at Stand-ground sluice. Where a power is in itself weak, but useful, every thing ought to be avoided which renders it weaker. Yet I
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can by no means apprehend, that if a dam were put across at Stand-ground, and no water to pass at all that way, the difference would, as matters now stand, become sensible at the out-fall.

It seems, then, that things are preparing for the last remedy, and I am glad to have it in my power to say, that a remedy every way adequate and certain yet remains, equally beneficial to the drainage and to the navigation, and that is no other than to build an out-fall sluice upon the mouth of the river.

I know that so much has been said and wrote against the putting sluices upon rivers, and stopping the tides, that there may be those who will start back at the very sound of the word sluice, as applicable to the out-fall of the river Nen, as now it may properly be called.

But be not alarmed; let us hear what may be said in favour of a sluice. I am not, indeed, for putting sluices upon rivers which are in a condition to maintain themselves open by nature; but, in the present case, nothing is more plain, than that the sands which are deposited in the river, from its out-fall to Knarr lake, and thereby obstruct the passage of the land flood waters to sea, causing them to break the banks, and overflow the whole country, are originally brought from the sea; it is also plain, that if those tides, whereby these sands were admitted, had been shut out, the sands would not have been there; it is equally certain, that if for the future the sands are shut out, it will prevent their increase; and if the flood waters shall roll any particle of sand that is now lodged in the channel of the river, from its present place towards the out-fall, that there will be no power acting in a contrary direction to cause it to return; it therefore follows, that the effect of the power of the land waters, whether greater or less, is to carry out the sands that now are lodged, and to deepen the channel of the river within the sluice.

Without the sluice, if the doors were to be always shut, a quantity of sand and silt would be very quickly deposited; but at a distance, where the river is of considerable breadth, and consequently the motion less rapid, the difference will be inconsiderable: for, whatever sand may be deposited without the sluice, that would have been deposited in the river within the sluice; as that water which is checked by the sluice, and so deposits its contents without, will check the influx of so much water as would otherwise have come in, and deposited its contents in place of the former: it hence appears, that, except near the sluice doors, no more silt will be deposited than would have been in case the water had obtained its free passage; nay, even less, for whatever
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checks the rapidity of the tide, prevents its bringing so much turbid matter along with it: it is true, that the power of the reflux is weakened also, even if we suppose the doors of the sluice to open, whenever the water without falls below the level of the water within; because the former part of the ebb is weakened by the want of the water that the sluice has stopped out; therefore, balancing the less quantity brought in against the less quantity carried out, we may lay it down, that the channel without the sluice will remain nearly in the same state as if there were no sluice at all; that is, in case the sluice be suffered to run whenever the level of the water will admit it; and as there is always something more of run near the tail of the sluice, than at a distance, this will again counterbalance the greater deposition near the doors; but if, instead of permitting the sluice quietly to run whenever the water without ebbs below the water within, we suppose that the land waters are kept pent in by land doors, till low water, and then the quantity of water that has been collected, discharged in a body; or when the supply of land waters are short, to discharge what has been collected, in two, three, or four, or even ten or fourteen tides in one: we shall hereby obtain an artificial application of a natural power, which will turn the balance greatly in our favour, by deepening the out-fall channel without the sluice. It is clear from reason, that the operation of a sluice thus worked is to deepen the out-fall channel as well as the inner; but whether in a considerable degree might be doubted, if this were the first of the kind; but that the operation of sluices, properly managed, is very great, is proved by incontestible experience. The out-fall channel from the sea to Dunkirk is maintained wholly by sluices, the effect of which, in the time of Queen Anne, was so great as to make a passage by which large ships of war were enabled to enter that port, and the erection and destruction of such sluices as have been from time to time adapted to the purpose of scouring and deepening the out-fall channel of this port, has been a bone of contention between England and France ever since. The canal of Middleburgh in Zealand, by which East Indiamen are carried up with their cargoes to that city, is kept open wholly by sluices; and where they have but little help, in point of depth, from the tides. The port of Ostend is kept open, and the canal from thence to Bruges, capable of navigating the largest colliers from Newcastle, is maintained by the operation of sluices. And as this is a case in point, I will beg leave to mention, that the old sluice of Ostend having been blown up and destroyed some time about the year 1751, in or about the year 1752 deputies were sent to England to view and inform themselves, whether they might not save the great expense of re-building this sluice, by allowing the tides to ebb and flow up and down this canal, as is the case with almost all the rivers in England; but there being here little land water to assist the ebbs in scouring, experience quickly convinced them, that without re-building the sluice, they would soon have had both port and canal silted up,

up, and the country drowned; accordingly, they proceeded to re-build and finish the same in the years 1753, 1754, and 1755, upon a most magnificent plan, and at a proportionable expense. Indeed, there is scarcely a port in Flanders or Holland, where something of this nature is not applied; but I mention the above, as having, with many others, been eye-witnesses to their effects, and as being the most considerable in similar cases; but, without going abroad, the great sluice lately erected at Boston, with the state and condition of the river before and since, will, I believe, be a strong illustration of this point.

Having mentioned Boston sluice, it will naturally be inquired, that, since I look upon an out-fall sluice as necessary for the out-fall of the river Nen, why I do not, like Boston, propose to carry out the drainage by the river's sluice, and thereby save the expense of erecting a new drainage sluice, and carrying down the sewer to the washway house. I answer, for these three reasons: in the first place, I propose the river's sluice to be built betwixt Wisbeach and the sea; and, therefore, to preserve the navigation even such as it is, on shutting out the tides it will be necessary to keep up the water higher within, than is consistent with the good drainage of the north level; and, indeed, if exclusive of the navigation, the waters were run so low as to drain the north level, they would be too weak to scour the out-fall channel; that is, as much as to say, the out-fall would then have the same defect as that of Gunthorpe now has, and, in effect, the north level would not be drained. 2dly, That supposing by the superior action of the land waters the out-channel could be kept open to the necessary depth to drain, yet the quantity of land flood waters coming down the river Nen is so much greater than those of the river Witham, that the drainage would be much more subject to be interrupted, by being over-ride by the river, and would be much less perfect on this account. 3dly, In case of drainage by the river's sluice, the river must be diked out, or a new river cut from the sluice to Guyhern, of a very large and deep channel, to answer this intent; and as a considerable sluice would be still needed upon the out-fall of the drains at Guyhern, in order to prevent the Nen's waters over-riding the drains in time of land floods; and, on the other hand, as the back drainage, by way of Shire drain, is already performed, and in a condition to perform its office, with a little help in the way of scouring; that is, after the defect of the out-fall is remedied; it follows, that the expenses of draining by the river would far exceed those necessary to complete it in the other way, and at last be less perfect, as by the back drainage the sewers can never be over-ride by the river's floods; and in case of any accident to the river's sluice, the drainage would not immediately be interrupted.

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When a sluice is established upon the river as aforesaid, it is very clear, that the accumulation of land waters will be highly necessary, and of great use; for this reason it will then be of great consequence, that no water is lost at Stand-ground sluice; and though I am not so penurious of water as to desire to debar the vessels penning through that sluice, of the supply of water necessary for that use, which, as I am informed, sometimes amount to sixty in a day, yet I would by all means recommend that the sluice be not run, as it sometimes is, two hours in a day, in dry seasons, by which, according to my computation, is wasted as much water as would pen through it 168 vessels: this I call an unnecessary waste of water; for though it may be necessary to the navigation below that sluice, upon its present construction, yet the shoals ought to be deepened, or the works otherwise altered, while they can work without flashes.

The great and powerful agent upon which I principally depend, to cleanse the river and open the out-fall, is the great land floods, which, being freed in a great measure from the checks of the tides, will, by their action within and without, gradually wear down a deep channel to sea, and I doubt not will in time enable vessels drawing eight and nine feet water, to go up to Wisbeach at common spring tides, and to give passage to such as now navigate at spring tides only, to navigate at all tides, and with a very little help to make a constant navigation for lighters to Peterborough. Thus will the navigation be greatly improved; the level secured from inundations, without raising the north bank higher than it now is, and will be a means of maintaining the out-fall channel of the drainage sluice free and clear of sands for a long series of years; and even of maintaining, in all probability, a good passage out to sea, even after the coast is extended much further out than its present limits, and thereby giving the whole every degree of permanency that the nature of the situation will possibly admit.

To this scheme I can see but two objections; first, that to maintain the navigation as it now is, to Wisbeach, before the deepening takes place we must constantly hold up the water as high as the ordinary spring tides rise at Wisbeach, that is, about four feet above its ordinary level there, and that in consequence of this, we may prevent the mills upon Waldersea fen, and Wisbeach hundred, from throwing their water into the river, or oblige them to throw it higher: I did not happen to think of examining this point when there, nor do Mr. Elstobb's papers fix it; nor yet do I know how far their right of so doing is established, so as to put a negative upon any other works to be erected upon the river; but supposing it so, the out-fall and descent in Shire drain will be so much improved by the methods proposed, that the whole may be drained that way, the water of Waldersea fen being brought in a tunnel under the river.

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The second objection is, the danger of the sluices choaking by ice, upon the break of a frost, when succeeded by the great land floods that are generally consequent thereon; this is perhaps the only solid objection to such a work, but then it is an objection to every work of the same kind; and as I do not know any other lasting way of keeping open this out-fall, I do not see any way of totally avoiding this risk; however, to make it the least possible, I would propose to make the sum of all the openings of seventy feet wide, equal to the width of Wisbeach bridge; but as I suppose that a far less quantity of opening would be sufficient for navigation, and the discharge of the ordinary quantity of land waters, I would propose to make one of the openings at least thirty feet of clear water-way; the doors of which not to be opened or shut by the tides or land waters, but by proper tackles and machines for the purpose, worked by men; and these doors not to be opened at all, but on occasion of great floods, when the others are found, or expected, to be insufficient; and though this may require vigilance and labour, yet, as the occasions of opening it will not be frequent, it may well be dispensed with, to avoid a greater risk. By this opening, will, at such times, be the principal run, which will therefore draw the largest pieces of ice towards it, and which may be so much the more easily broken and managed, than in passing smaller openings, that I apprehend the risk will not be great upon the whole, or any real objection to the undertaking.

After the first erection of the river's sluice, some little help may be expedient, to give the land floods more advantage in the beginning; and that is, to dike out a channel of the river from Guyhern, or a little below, to Knarr lake, and to take up the gravels that are lodged in the leam or river above; as also by the use of the hedge-hog to take proper times of loosening the sands between the horse-shoe and the sluice; but I apprehend that after the first winter, nature will perform the rest, when properly directed by art, in the management of the sluices.

Having advanced thus far, the placing of the sluice and expense of the works proposed, will be next inquired after; but as the eligibility of the proposition is the first thing to be determined, I must reserve a minute discussion of these matters to a future consideration; and, indeed, it will require a re-examination of the premises, with this particular view, to be able to do it with precision; however, to give the best idea thereof that I now can, I would place the sluice somewhere between Walton dam and the river's end, and lay its apron almost as low as low water at the washway house.

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It is said, that there was once a sluice built across the river at the Horseshoe, but as it failed in a few tides after it was opened, its good or bad effects could not be known from experience; and as its failure was undoubtedly owing to insufficiency in its construction, no argument against the proposition will fairly arise from thence.

A probable ESTIMATE of the proposed works.

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The great sluice, with its proper appendages, - - - - -	8,000
Expenses in first deepening the river, - - - - -	2,000
Expenses in scouring out Shire drain, putting it in order, and laying Clow's cross sluice three feet lower, - - - - -	2,500
To cutting a new sewer, supposed two miles in length, from Gunthorpe sluice to the washway house, partly through the salt-marshes, partly through the in-grounds, supposed at an average twenty feet bottom, sixty feet top, and ten feet deep, at four-pence per yard, including drainage, comes to - - - - -	2,614
To a new drainage sluice at washway house of three seven feet tuns, the apron to be laid two feet (if possible) below low-water mark, - - - - -	2,500
The land for the aforesaid cut and cover will contain about forty acres; the value I am not a judge of, but if, for the sake of filling up a blank, we suppose it £30. per acre, this article will be - - - - -	1,200
To contingencies upon the above articles, at ten per cent., - - - - -	1,881
	20,695

J. SMEATON.

Austhorpe, August 22, 1768.

P. S. In answer to the question concerning the enlargement of Gunthorpe sluice by way of relief, till something more effectual can be done, I am of opinion, that if the execution of the scheme of carrying the out-fall to the washway house is speedily resolved upon, as this is the first part of the work that should be put in execution, it is scarcely worth the while to alter Gunthorpe; but if that meets with difficulties and delay, then I am of opinion, that the floor of Gunthorpe, from the information I have had, is large enough and strong enough to carry three six feet waterways; and I am also of opinion, that the affair of scouring by the reservoir should be again tried.

I am of opinion, that the embanking of salt marshes is a means of more speedily gaining land, and removing the low-water mark to a greater distance; but I am also of opinion, that if the salt marshes were not to be embanked, the shore would yet keep advancing into the sea; and therefore some more effectual means than the non-embankment of salt marshes must be used to keep the out-fall open, and which, if put in practice, it is not much concern, whether the salt marshes are embanked or not.

J. S.

HATFIELD

HATFIELD CHASE LEVEL.

The REPORT of JOHN SMEATON, engineer, upon the means of improving the drainage of the level of Hatfield Chase.

THE perfecting of the drainage of Hatfield Chase, whether considered with relation to the proprietors of lands therein, or the public in general, is undoubtedly a great object; for if we consider the vast quantity of good ground in a high state of cultivation, whose crops are rendered uncertain by the want of a complete drainage, or the vast extent of common, consisting in general of naturally good land, and which, if completely drained, might be taken in and inclosed with great advantage to the owners, together with the great quantities of meadow and pasture ground, that, by an uncertain drainage, yield but an uncertain profit, one is naturally led to conclude, that if nature admits of this drainage being made certain upon so great an extent of surface, it will amply repay any moderate degree of expense.

According to my information, and indeed the thing itself shews it, the evil attending the draining of these levels does not so much consist in this, that the water cannot be got off the surface in dry seasons, as that the rains send down so great a quantity of upland rivers by the course of the river Torne, during the winter, which overflowing the banks thereof makes it way over, and upon the surface of the levels, so that those parts of the levels that lie low relative to their distance from the out-fall, cannot be got clear of water sufficiently early in the spring to undergo the proper cultivation, or to be in a proper condition to bear a crop; but when this happens to be the case, that the latter end of the winter and the beginning of spring proving dry, the lands are in proper condition for a crop; yet, if the summer or autumn proves rainy, the Torne again, by overflowing its banks, and otherwise obstructing the course of drainage, lays many of the lowest parts of the level under water, so that the crops thereon are either lost, or greatly damaged, which was indeed the condition of it at the time I viewed it, and made my observations, so that, relative to the business I was upon, I could not have seen it at a better time.

Seeing the levels in the situation I have described, one is naturally led to examine, whether this imperfect state of the drainage be owing to an original imperfection in the construction of works of drainage, or have grown imperfect in length of time; and

on this head I am clearly of opinion, that in their first execution they were greatly imperfect; for though there would appear a striking difference between a drowned country during the whole of the year, (some small tracts of rising ground here and there excepted), and its present state, whereof every part bears crops of some kind in some seasons, yet it is manifest from certain signs, that the drainage could never be much better than it is, and several parts could never be so good as they now are.

It so happens, that between the part of the levels the most oppressed with water, and the river Trent, which is the natural out-fall, there is not only an interposition of higher ground, but in this higher ground, at a certain depth, there are strata of rocky matter, interspersed with plaister or alabaster, which, though not very hard, is yet considerably more hard to work upon than common earth or clay, and whether the expense of digging in these strata, in order to sink the drains and aqueducts in this matter to a greater depth, or the want of sufficient fore-knowledge and experience to see the necessity thereof, is at this length of time perhaps altogether uncertain; yet true it is, that from hence the greatest part of all the evils that have attended this level from the first improvement to this time, have had their source; for, in order to avoid the necessity of cutting into these strata of rocky matter, which appear in the bed of the present artificial course of the river Torne near the Hurst, they have been under the necessity of confining the waters of Torne in a course by artificial banks, through that very part of the level country that was most oppressed with water, so that the surface of the Torne being at all times above soil, and in time of freshes from downfall water in the upland country, considerably above the level of the country to be drained, it is easy to see the consequences; for as the soil, during almost the whole of the tract, extending for six miles in length, is a black peat earth, those banks, (however they may have been raised at first), being very liable to be trod down and poached with cattle, the fact soon would be, and now is, that not being high enough to confine the waters of the Torne after any thing of considerable downfall, the river then overflowing and breaking them down, covers the surface of the low grounds that most want to be drained. Those low grounds that are near the course of the Torne, are subject to be the most immediately and in the greatest degree affected, that is, whose waters are discharged at Althorpe sluices, by which the Torne has its out-fall into Trent; for these waters, thus got over upon the surface of the lowest grounds, gradually pass by the drains to the common out-fall, and in their way keeping the common drains gorged with water, they, in consequence, gorge those that lead from parts remote from the Torne, and all meeting together at the out-fall, very much retard and prevent the drainage of the whole level. These, I beg leave to observe, are very capital errors in the original construction, and though the enlarging
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and deepening the north river, (in some places between two and three feet), by cutting into those beds of rocky matter and plaister which had never been stirred before, is in itself a great improvement, which in the more dry seasons is, and will be very manifest, as it was to me at my first visit to the levels; yet, after the Torne has topped its banks, and all the drainages meet therein, as was the case when I was last there, the immediate benefit hence arising was not so great as might have been expected, and as they will be when the whole is made suitable to that part already so judiciously done.

From what has been said, it may be in general gathered, and in which I doubt not I shall be corroborated by those that best know the levels, that the main proposition for perfecting the drainage of Hatfield Chase, will be that of conveying to the Trent the waters of the Torne, without overflowing its banks, or over-riding the internal drains at any time, except those of extreme wet seasons in the winter.

In order to effect this, nothing is more clear than that there must be a sufficient capacity of aqueduct to convey, and of sluices sufficient to let out the water so conveyed, in both which essential particulars the original scheme has been so very remarkably deficient, that in this, as in many other instances, I have had the opportunity of seeing they have drained as if they were in fear of doing too much.

For remedy of the evils complained of as above mentioned, a new out-fall drain and sluice have been suggested and pointed out to me, to a part of the Trent, about seven miles below the present out-fall of Althorpe sluices, to a place a little above Waterton, to which place I am informed there is a fall at low water of the Trent's surface of above four feet, and which, having been repeatedly levelled by different persons, I take for granted. Now, an addition of four feet, added to the present fall into the Trent, from the several points of the surface of the level to be drained, is, undoubtedly, a very valuable acquisition, and which obtained, and every advantage drawn from it that it is capable of, will certainly render the rest of the business more easy, and more nearly reduced to plain sailing, which every thing of this kind ought to be, as much as possible. There is also another very desirable circumstance attending the place of this new out-fall, for, as I am informed, so low down in the Trent as the point near Waterton, as above specified, a flood in the Trent is scarcely sensible at low water, so that in the greatest downfalls the sluice there would run at every low water, whereas, according to my information, the flood water of Trent sometimes continues so high at the lowest ebb of tide, that for several tides together it over-rides the drainage water, so as not to suffer the sluice doors at Althorpe to open, and the sluice-keeper says he has known
them

them to have been kept shut for five days together. These are advantages of the new situation, very material, and not easy by other means to be as fully procured; so that though according to my estimation, it will cost the sum of £6165, in addition to what I would recommend to be done, yet, if all parties are agreeable to this being done, and the additional money can be raised, I think it will be well laid out, as being of permanent utility to the whole country, which may have occasion to utter their waters thereby; and though to the execution of this I see no natural difficulty, yet, as I understand that the whole course of the proposed out-fall drain lies through parishes and lordships, wholly unconnected with participants concerned in Hatfield Chase, in case difficulties should arise in reconciling these different interests, it seems to me of consequence to that body of gentlemen, and the country at present depending upon their undertakings, to shew how the level of Hatfield Chase may be drained in a very competent manner, without going out of their own boundary. And here I must beg leave to remark, that having been consulted in the year 1764, upon the means of improving the drainage of that part of the level of Hatfield Chase*, dependant on snow sewer, which conducts the water south of the isle of Axholme to the Trent at Ferry sluice, in like manner as the north and south rivers conduct the waters north of the said isle to Althorpe sluices, I say, had the gentlemen concerned been so lucky as to have given full credit to the doctrines and directions contained in my report thereupon, they would, before this time, have practically seen the advantages in so strong a light, that, applying the same reasoning to the north-side drainage, as is there applied to the south, they would have seen their way through this also. What I have to do, therefore, is to enlarge upon what is there contained, and adopt the same reasoning more particularly to the circumstances of the present subject.

SCHEME OF IMPROVEMENT.

FACTS.

1st. The threshold of the big sluice at Althorpe, I found to lie six inches below low water of the Trent there, the evening of the 16th of September past; but the preceding season having been showery, I conclude that, in dry seasons, the Trent ebbs down so as to be even with the threshold of that sluice at low water.

2dly. I found the thickness of the water over Althorpe sluice threshold, one hour before low water, the same day, to be one foot, and in passing the sluice there was one foot fall from the surface of the north river, at the flow running water a little above the sluice, to the surface of the Trent at that time. From whence I conclude the
sluice

* See Vol. I. page 130.

sluice was then vending at the rate of 6000 cube feet of water, amounting to 166 tons per minute.

3dly. The water's surface was then fallen two feet two inches below its mark before the doors opened, which mark was four feet $1\frac{1}{2}$ inch above the threshold.

4thly. At the Torne end $2\frac{3}{4}$ miles above the sluice, the water did not settle above nine inches in the whole tide.

5thly. In viewing the different parts of the level, I found the ground about the Tunnel Pit, and particularly that part north of the Torne and west of the New Idle, to be the most oppressed with water, and, therefore, relative to its distance from its out-fall, the lowest; here they were cutting corn up to the boot-tops in water. What therefore will effectually drain this farm, will furnish the means of draining all the rest.

6thly. I found the surface of the river Torne at the Tunnel Pit bridge, two feet $6\frac{1}{2}$ inches above the surface of the stagnant waters upon the said farm, and as I judged it would take a reduction of eighteen inches to run the water well off from the general surface of the lowest parts, and one foot more to produce a competent drainage; hence then it appears there will be a fall of three feet eleven inches from the surface of the drains necessary to drain this farm to the threshold of Althorpe sluice.

7thly. I found the surface of the river Torne, at the Tunnel Pit bridge, eight feet $11\frac{1}{2}$ inches above the level of the threshold of Althorpe big sluice, to which I shall constantly refer.

8thly. The Torne was, during the five days the above levels and observations were taken, within a few inches of over-topping its banks, quite away from the east end of the new cut, a mile below Tunnel Pit, to the Crooked Dyke End, and continued at the same height at Tunnel Pit bridge, with one-eighth of an inch.

Now, had the big sluice tunnel at Althorpe been one foot wider, that is, fifteen feet wide instead of fourteen, and its threshold laid two feet deeper than with the same descent from the drain into the Trent of one foot, this sluice would have run 21,000 cube feet of water, (amounting to 583 tons), per minute, and would have run 6000 cube feet, the quantity discharged as above specified, with one inch of fall. Hence this circumstance alone would have reduced the water over the whole body eleven inches.

I would,

I would, therefore, propose to rebuild the lesser sluice, whose clear water-way is scarce eleven feet, and to make it fifteen feet clear, and to lay its threshold two feet lower than that of the present big sluice. The south river, which answers to this proposed new sluice, is now diking out to a twenty-feet bottom, and to be sunk one foot below the present sluice-floor head, which is nearly on a level with the big sluice threshold. This enlargement to go from the sluice to Durtnefs bridges; but to make this drain, called the South River, suitable to the new sluice, it should yet be deepened one foot more, and widened so as to preserve a twenty-feet bottom at that increased depth, and to be kept upon a dead level from the sluice to Torne End. The further communication with the south, as well as the north river, to be shut off by cross banks, so that this part from the south river, from Torne End to the sluice, will be wholly appropriated to the discharge of the river Torne. From Torne End to the Great Elbow, at Hurst, I propose to enlarge and deepen the present course of the Torne, answerably to the former, that is, to a twenty-feet bottom, with proper batters, carrying the bottom from the south river no further dead level, but upon a plan gently ascending, so as to rise two feet at the Tunnel Pit; that is, the bottom of the river at Tunnel Pit, and the present threshold of the big sluice at Althorpe, (or low-water mark in Trent), will then be upon a level.

In this case the rock and plaister bottom, near Hurst, will be to deepen in some places $4\frac{1}{2}$ feet, and the water of Torne, (running the same quantity as I saw it when near bankful about Tunnel Pit), will have its surface reduced below the present bottom.

From the Great Elbow, at Hurst, I propose to make a new cut through the common in a straight line to the elbow below Ross bridge, in length about two miles, which will cut off all the most disadvantageous angles, shorten the whole length half a mile, and leave the present course of the Torne between these two points, to act as a drain for purposes that will be shewn hereafter. This new cut to be carried on with a twenty-feet bottom, and, after joining the elbow of the present course below Ross bridge, to widen and deepen the present course to a twenty-feet bottom, inclined as before specified to Tunnel Pit.

At Tunnel Pit, the new river being admitted three feet six inches deep of water, its surface will then be near $5\frac{1}{2}$ feet below its surface when I levelled it the 18th, 19th, and 20th ult. It will be two feet eleven inches below the surface of the stagnant water upon the Tunnel Pit farm before mentioned, and one foot five inches below the lowest

parts

parts of the general surface of the said farm, that is, five inches lower than as above stated, to produce a competent drainage there; that is to say, coming to a fixed mark of which the country will have an idea; its surface will be within six inches of the threshold of the second stop-gate, entering the tunnel under the bed of Torne, at Tunnel Pit. At the same time there will be a fall of three feet from the new river's surface at Tunnel Pit to Trent's surface at low water, as I found it the 16th, and this, in a course of $8\frac{1}{4}$ miles, will allow four inches fall per mile, besides a fall into Trent, in passing the sluice of three inches, and this is taking the water of Torne to be discharged into Trent, (that is Torne bank-full), as I found them; whereas, in all dry seasons the surface of the Torne will be considerably lower, as above specified; so that we may say in all ordinary seasons, all the grounds adjacent to Torne on both sides, will drain by stop tunnels, or holds, as they are called, in this level into the course of the river Torne. However, as the river is liable not only to be swelled considerably by rains, but to be obstructed by the growth of weeds, which, as they are taken more or less care of, are liable to hold up the water more or less in the river; and though I think it very practicable to make a good drainage of all the lands on each side the river into Torne, yet, as there are sure means of doing it otherwise, I would by no means propose those lands to depend wholly upon the exact keeping of the river. I would propose, therefore, that all the soil that will be dug out of the course of the river, which will be a very sufficient bulk, to be disposed, bank-fashion, on each side the river, whereby the Torne, thus embanked, will be sufficient to hold in the flood waters at all times from ever getting upon the surface of any of the lands west of the high grounds at Hurst, so that the flood-waters being conveyed away as they come, through the low country before described, those low grounds will, at the decline of the upland floods, have nothing to vend but the downfall water upon their own surface, and thereby having little to drain themselves, will not oppress and gorge the common drains for a long while together, and thereby prevent, in like manner, the drainage of the more distant, though higher parts of the country.

Having thus, in all common times, reduced the river Torne at least one foot five inches within soil, at the Tunnel Pit farm above mentioned, and still more so with respect to the grounds on the south side of the river, which I esteem, at an average, to lie six inches higher, I propose to remove the tunnel entirely, and to make the New Idle communicate with the river Torne on both sides, by stop-gates, so that whenever the surface of the Torne is lower than the surface of the New Idle, the drainage will be into the river, and whenever the contrary, or so on either side, then the respective gate to be shut, and the drainage go on by other means that will be described. But I judge these gates will be of further great use in very dry seasons, in letting fresh water out of

the Torne into the drains for watering of the cattle, and thus the Torne, instead of being the bane and pest of these levels, will become a valuable refreshing stream.

That it may not be doubted whether the Tunnel Pit farm contains the lowest grounds in the level, relative to drainage that lies near the river Torne, I beg leave to state these further facts :—That upon the surface of the Torne I found a rise from Tunnel Pit bridge to Gate High bridge, of no less than two feet seven inches, in a course of about four miles. The surface of the water at Gate High bridge being no less than eleven feet $6\frac{1}{2}$ inches above Althorpe threshold, and a further rise to the Crooked Dyke End, (where the Torne enters the level of Hatfield Chase), of $4\frac{1}{2}$ inches. So that from the entry of Torne into the level of the Crooked Dyke End, to its departure into the Trent at Althorpe, being a course of $12\frac{3}{4}$ miles, there is a fall of no less than eleven feet ten inches, a very sufficient allowance certainly to make a very complete drainage. I must, however, observe, for the sake of reconciling my levels with others that may have been taken, that the surface of Torne at Gate High bridge was higher by $2\frac{1}{2}$ feet than when taken by your surveyor Mr. Scott, in a dry season. This premised,

I observed, that the grounds that were the most oppressed with water in the neighbourhood of Gate High bridge were those lying to the north of Torne, and east of Gate Wood road, between the Torne and the drain called Ring Dyke, and as those grounds did not appear more overflowed, and about the same depth below the surface of the Torne, it will follow, that they lie higher than those of Tunnel Pit farm by the afore-said rise of two feet seven inches, so that when the Torne's surface is reduced at Gate High bridge, they will even drain into Torne there; but much more safely and effectually by the course of the Ring Dyke, which goes from thence through the Tunnel Pit farm, and falls into the New Idle there, which drain will then want nothing but a more perfect scouring and cleansing to do its intended office, in draining those grounds, and those still west, which lie proportionably higher. And N. B. The lands on the south of Torne lie universally higher than those on the north; they, therefore, will in like manner, by a proper cleansing and scouring, convey all their waters by the present courses to the New Idle south of Tunnel Pit, that the others are described to do respecting the grounds on the north. Conformably to what has been already stated, it will be absolutely necessary to prevent the Torne overtopping its banks in this district, to reduce it also within soil, and at the same time procure matter to form sufficient banks to confine it in extremes of land floods. For this purpose, I propose to carry the Torne in its present course nearly so, that its bottom shall rise from Tunnel Pit to Gate High bridge two feet six inches, and contract from a twenty feet bottom to eighteen, that is

to say, to continue an eighteen feet bottom to Wroot Brick bridge; a nineteen feet bottom from thence to Fullick Nook, and an eighteen feet from thence to Gate High bridge, which will be nearly six feet lower than I found it; a pit of two feet, which will be six inches per mile nearly, the same as at present, there will then be three feet depth of water at Gate High bridge, which will be nearly six feet lower than I found it, and will be at least two feet within soil of the lowest adjacent grounds, and even below the bottom of the present river. From what has been said, I trust it will appear that the discharge of the waters of the Torne has been very well provided for in all common times, so well, that the only distress that can happen will be when the river Trent is in such a state as that the doors at Althorpe continue shut for five days, as has been reported; but it must be observed, that as at present the banks of the north river are incapable of penning in the water to above five feet above the threshold of Althorpe sluice (the north and south river having an open communication between them), it will follow, that wherever the Trent in time of flood continues more than five feet above the threshold, though it was but an inch during the whole five days, yet the doors will never open, as the flood waters of Torne will have an opportunity of expanding themselves over the level; whereas, it is possible, that could the Torne have been confined, so as to have risen six feet above the threshold, then the doors might not have missed opening above two days of the aforesaid five: but to give this matter a much better chance, and, indeed, a very good one in such cases, with the matter that comes out of the south river from Althorpe to Torne End, I propose to make good the banks of that river, so as to be of nine feet above Althorpe threshold, which is full four feet higher than the banks are now capable of penning, and which is as high as the high water of neap tides in Trent, at Althorpe; so that unless the river Trent in time of floods should continue at low water as high as the ordinary heights of the tide at high water neap tides, the gates will run once in every tide, and, as I apprehend, will as rarely be stopped by a single tide when the south river banks are fully charged by the land waters, as they now are for five days together; and when the little sluice is re-built as above mentioned, it will discharge such an amazing quantity of water, upon a declivity of three or four inches, that it will seldom happen when the sluice runs at all, but that it will discharge as much water in an hour as the Torne accumulates in a tide*, and after the floods begin to abate the water will be run off so quick, that as much reduction will be made in ten days as now will take two months.

* If the present sluice runs 6,000 cube feet per minute, it will run 360,000 cube feet per hour, and 2,160,000 cube feet in six hours, supposed the average time of running for a tide; the new proposed sluice would on a descent or difference of four inches from the drain to the Trent surface, and surface in the case mentioned, discharge no less than 2,640,000 cube feet per hour.

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What principally remains is to shew how the internal drainage is to be provided for, when over-rode by the Torne; and the principal part of this difficulty consists in running off the waters collected in the New Idle at the Tunnel Pit, both on the north and south of the Torne, when the stop-gates there are obliged to be shut. I shall begin with the south side: and for this purpose,

It is to be observed, that the present course of the Torne, from the elbow next below Ross bridge, to where the new river will join it at the great elbow west of Hurst, will be deserted; this, I would propose to dike out and scour, which it will want in places chiefly from Shore Nook bridge to the said elbow below Ross bridge, and from thence to continue a new drain nearly parallel to the course of the Torne, to join the Gadinstake drain and New Idle near the present stop-gates of the Tunnel. This will be capable of running off the downfall water nearly to the level of the Torne's reduced surface at the Hurst elbow, and where I would put a small stop sluice to prevent the Torne's reverting in flood seasons, at which time all the internal drainages will be stopped, but which, (by the aforesaid provision) having nothing to run off but their own downfall waters, will soon be done; that is, as soon as the flood water is run off in Torne, and that will be as fast as in Trent, upon which last, in fact, the whole will then depend.

The most overflowed part of the level south of Torne, and the most difficult to be drained, is generally reckoned to be the Mizen Deep and the grounds about the Bull Haffocks. The Mizen Deep is a remarkable flat track of ground, very far from being the lowest in the level, but being remote from its out-fall, and near that part of the level bordering upon the New Idle, where the water runs indifferently towards the Tunnel, and so to Althorpe, or towards Snow sewer, and so to Ferry sluice, according as it makes the best descent; and as the waters from the New Idle south of Torne are as I now find only suffered to run at the Tunnel two days per week, and the works formerly proposed for Snow sewer are now only executing, but have never been executed with the full effect; this track has hitherto remained the opprobrium of this level's drainage. Now, from my observations, it appears that the general surface of the track of ground called Mizen Deep lies at least one foot higher than the general surface of the low parts of the Tunnel Pit farm, and two feet five inches above the proposed reduced surface of Torne at Tunnel Pit as above specified, and two feet eleven inches above the threshold of the stop-gate of the present tunnel; and further, when the deserted course of Torne is scoured out, and a suitable drain brought up to the New Idle at Tunnel Pit south side, as already mentioned, the surface of the New Idle will be capable of being reduced by
this

this drain to a level with the threshold of the tunnel's stop-gate, so that there being a descent of two feet eleven inches from the surface of the Mizen Deeps, along the course of the New Idle, in the space of about two miles (which is already a good and sufficient drain) there can be nothing more wanting effectually to drain the Mizen Deeps, and if those, all the grounds less oppressed of course.

I must further observe, that on examining Ferry sluice, I found it substantially rebuilt according to my former report; it was discharging a very good body of water with only a single inch of descent in passing through the sluice, and but five inches fall from the drain to the Trent at low-water, the other four inches being occasioned by the outfall passage between the doors and the low-water mark of Trent, not being proportionably deep and clear of silt. There were also some inches deep of warp upon the floor, and still more in the drain above the sluice, occasioned chiefly by the sluice doors being out of repair and leaky, which would not be the case were every thing made suitable, in order, and the proper means used; from the sluice, for a mile upwards, the Snow sewer drain has been deepened according to the proposed dimensions in my former report, by sinking into the strata of rocky matter, and alabaster, as described near the Hurst, that had never before been stirred; yet above this deepening, the water was so held up by want of capacity in the drain, that at two miles from the sluice, the surface of the water of the drain was full two feet six inches above the surface of the water of the said drain, at the entry of the river; and had the drain been completed in like manner, to the place where Monkholm drain takes off (above which Snow sewer, in its present state, seems very good) this alone would have reduced the water over the whole depending drainage, at least two feet in its then flood state, and in dry seasons considerably more. From the above facts and observations from the Snow sewer to its head, where it joins the New Idle south of Torne, I conclude, that the surface of the grounds of the Mizen Deeps, lies full three feet above the low-water of the Trent at Ferry sluice, so that the course not being (by estimation) much above four miles, it is not to be doubted, but that when Snow sewer is completed, and the leading drains put in order, but that this track of ground will admit of a content drainage also.

The country south of Torne being thus adequately provided for, we shall now go to the north side; and here, after a total separation of the Torne from the drainage as before proposed, there is little remaining to be done; the north river is already deepened, and rendered of sufficient capacity, being a thirty-two feet bottom, and carried to Durtnefs bridges, at least six inches below the threshold of the big sluice
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at Althorpe; the Old Dun has been diked out and deepened, with sufficient and proper capacities as far as the double bridge, within a mile and a half of Torne: the Anchor drain has also been diked out and deepened, from Durtnefs bridges to the elbow at John Coulmon's shuttle, and from thence across into the drain that leads the water by the side of the Brier hills, from Woodhouse common, which last, on my last view, appeared to be the most oppressed with water in all the district of the levels, yet, from my observation, its mean surface lies at least five feet above Althorpe threshold; so that during my stay there was nothing to hinder all the grounds dependent on these capital drains from being in a complete state of drainage, but the continual pouring in of the river Torne at Torne End, into the north river, which bringing down water nearly as fast as the sluice * could vend it, kept the north river, though otherwise a very capacious drain, so constantly filled up and gorged, that the water at Durtnefs bridges was from four feet to four feet one inch and a half, and never lower than three feet nine inches above Althorpe threshold, the whole time I was there, and yet the surface of Brier hills was nearly clear, and Woodhouse common with a few inches; now, if the Torne had been entirely separated from the north drainages by the north river, and carried into Trent by the south river with a separate sluice, I look upon it as a certainty, that in the state of season I found it, the big sluice at Althorpe, that answers to the north river, would have run off all the other drainages; so that the water at Durtnefs bridges should never have been more than two feet above the Althorpe threshold, and there would have been a better fall at a medium by two feet, from the surface of all the grounds that drain hither, and consequently a very complete drainage ever to Brier hills and Woodhouse common.

Furthermore there is dependent on this drainage, a long tract of low grounds that runs up toward Armthorpe, called the Uggins Carrs, which, though oppressed with water on account of their being more remote from their outfalls, yet, as this tract of country appears to rise even more than in proportion to the distance, what will effectually drain Woodhouse common, will furnish the means, by sufficient leading drains, to drain these also; but as I think the drain along side of Brier hills not sufficiently capacious to receive the drainage of so extensive a track, it appears proper, that the cross drain leading from this into the Old Dun, at the place called No Men's Friend, should be deepened, and also that the continuation of the said drain should be enlarged and deepened from where it turns off into the Anchor drain, to its other outfall into the New Idle, between Sand toft and Durtnefs bridges.

* N. B. The south river being at this time diking out, very little water was discharged by the lesser sluice at Althorpe, which answers to the south river.

It yet remains to observe, that the most material of all the works that want to be executed, is for the drainage of these parts of the levels depending upon the New Idle, north of Torne; and that is, the diking out, deepening, and enlarging of the New Idle itself, between the Tunnel Pit and Durtnefs bridges. This drain, like several others, passing from a low through a high ground, as about Sand toft, is much straitened in dimensions both of width and depth, passing this high ground. This drain should be taken up at the depth of the present bottom of the north river, and carried on so as to rise but six inches at the Tunnel Pit; that is, so as to be there upon a level with Althorpe threshold, the same as the bottom of the river Torne: but supposing the water at Durtnefs bridges kept within two feet above Althorpe threshold, and allowing the drainage water in this drain a fall of three inches per mile, this, in three and a half miles, will be ten and a half inches; that is, the surface of the water in the New Idle at Tunnel Pit, north, will be two feet ten and a half inches above Althorpe threshold; that is to say, eight and a half inches below the surface of the river Torne, in the state we have supposed it; two feet one inch and a half below the general surface of the lowest parts of the Tunnel Pit farm, and two and a half inches below the threshold of the stop-gate of the tunnel; and which surface, in dry seasons, or rather in the beginning of a dry season after a wet one, may be further reduced if found necessary. It appears to me, that the New Idle should be made an eighteen feet bottom to the New drain, and a fifteen feet to the Tunnel Pit.

I mention only such matters as happen to occur with respect to the particulars of the improvement of the internal drainage, because it would require much more time, and more observations, to say exactly what should be done, or what dimensions given in the more minute parts; my purpose at present is to point out the general outlines of a scheme, whereby the whole of these extensive levels might be put in a complete and secure state of drainage, leaving the detail to be more minutely specified hereafter, in case the general plan be approved to be carried into execution: because, if not carried into execution, the entering into these particulars would only be so much loss of time; and I trust I have been sufficiently explicit, that the validity of the scheme itself may be judged of: for the same reason also I avoid entering into the detail of what appears to me might be done in the way of improvement of the works, in case the business should not be judged proper to be entered into upon so large a scale as I have endeavoured to explain; the present proposition, as I have understood it, is to give a scheme that if possible may be sufficient effectually to drain and secure the whole level; and in doing this, as boundaries and properties are become in a great measure settled by the present course of the drains, I have endeavoured, as much as possible, to keep

keep the same courses, without considering how far the works might have been laid out to more advantage, supposing nothing had been done.

I shall now conclude by observing, that from the capacity of the new-proposed sluice at Althorpe, that in all moderately dry seasons, it will run off the Torne, and all the south-side drainages, considerably beneath those of the north river by the present big sluice; I would, therefore, as an occasional help to the north drainages propose to make a communication between the north and the south river, a little above the sluice house at Althorpe, with a stop-sluice thereon, with pointed doors towards the south river; and, furthermore, to have a staunch erected upon the south river of equal width with the proposed sluice above the communication, capable of penning occasionally the waters of Torne to the height of four feet above the threshold of the present big sluice, which staunch will have a threefold use. 1st. It will, by shutting down when the out-fall sluice doors are shut, prevent the warp that will always, more or less, get through the doors from getting further up the river. 2d. By shutting down occasionally to stop the Torne, in order to give the north river's waters a better opportunity of escaping by this deep sluice through the communication. And 3dly, by penning in the Torne at convenient seasons, and letting it go at low-water, to produce a scour, in order to drive out the warp and silt brought in by the tide, and deposited between the sluice and the staunch.

J. SMEATON.

Austhorpe, 7th September, 1776.

ESTIMATE for the execution of the new works proposed for the improvement of the drainage of the level of Hatfield Chase, exclusive of a new out-fall, by JOHN SMEATON, engineer.

	£	s.	d.
To enlarging and deepening the south river to one foot deeper than the present undertaking, that is, so as to be two feet below the level of the threshold of the big sluice at Althorpe, to be twenty feet bottom, and carried upon a dead level to Torne End, this is supposed in addition to what is now doing, being in length 2,207 chains, containing 27,630 cube yards, which, including drainage and banking, at four-pence,		460	10 0
To digging out by the course of the river Torne to a twenty feet bottom, inclined so as to rise from the former two feet at Tunnel Pit, the length from the Torne end to the great elbow west of Hurst, being 101 chains, this supposed the same as if dug out of the solid, on account of the managing the Torne's water, will amount to 97,062 yards, which, on account of the depth and rocky bottom, including drainage, is reckoned at four-pence per yard,		1,617	14 0
Carried forward		2,078	4 0

	£	s.	d.
Brought over	2,078	4	0
To digging a new course for the river Torne, from the elbow at Hurst, to the elbow next below Ross bridge, to a twenty feet bottom, with proper batters conformably to the depth before specified, being in length 16,655 chains, or 2 miles 655 chains, will contain 150,942 yards, which, including drainage, at three-pence half penny,	2,201	3	6
To digging out the river from the elbow before Ross bridge to the east end of the New Cut, from the former length, being the further length of ninety seven chains, or one mile seventeen chains, keeping a twenty feet bottom, conditioned as before, will contain 87,336 yards, at three-pence half-penny,	1,273	13	0
To digging out the river Torne, and embanking the same according to its present course, from the east end of the New Cut to Tunnel Pit bridge, being in length 105 chains, that is, $1\frac{1}{4}$ mile and five chains, to a twenty feet bottom, conditioned as before, which, on account of trouble in diverting the Torne's water, is supposed the same as dug out of the solid, amounting to 48,474 yards, which, including drainage of the water, at three-pence half-penny,	706	18	3
To digging out the river Torne, and embanking the same according to its present course, from Tunnel Pit to Gate High bridge, so that the bottom may rise in that length two feet six inches, and diminish in breadth from twenty feet at Tunnel Pit to eighteen feet at Gate High bridge, being for the same reasons estimated as dug out of the solid, which, being 335 chains, or four miles fifteen chains, will contain 114,708 yards, at three-pence half-penny,	1,672	16	6
To digging out and embanking the river Torne, according to its present course, from Gate High bridge to Crooked Dyke End, so as to conform to the new river at Gate High bridge, and to the old one at Crooked Dyke End, containing 6,844 yards, at three-pence half-penny,	99	6	2
Total of digging of the Torne,	8,032	1	5
To cutting a new drain for the south drainage from the New Idle, near the stop gate at Tunnel Pit, to the present course of the Torne, at the second elbow below Ross bridge, being in length 218 chains, and on a fifteen feet bottom, containing 53,289 yards, at two-pence half penny,	551	1	$10\frac{1}{2}$
To diking out the river Torne where wanted, from where the drain falls into it, to the Hurst elbow, being supposed in length 110 chains, that will want at a medium two feet deep, upon a fifteen feet bottom, will amount to 9,142 yards, at two-pence,	76	3	8
New drain making,	631	5	$6\frac{1}{2}$
To digging of the Torne,	8,032	1	5
Total of spade work,	8,663	6	$11\frac{1}{2}$

CONSTRUCTIONS.

	£	s.	d.
To building a new sluice at Althorpe south river out-fall, of fifteen feet clear water-way, and the threshold to be laid two feet below that of the big sluice on the north river, including the present sluice, taking the same up, the dam to Trent, &c.	1,500	0	0
The communication sluice and cut, - - - - -	500	0	0
The staunch on the south river, of fifteen feet water-way, and threshold as deep as the out-fall sluice, - - - - -	250	0	0
To six carriage bridges of £120. each over the Torne, - - - - -	720	0	0
To six private bridges of £60. each over ditto, - - - - -	360	0	0
To a road bridge over the new drain, - - - - -	80	0	0
To a private bridge over ditto, - - - - -	40	0	0
To a stop tunnel to the old course of Torne at Hurst elbow, - - - - -	40	0	0
To two stop gates at Tunnel Pit, £60. each, - - - - -	120	0	0
Constructions, - - - - -	3,610	0	0
Spade work, - - - - -	8,666	6	11½
Neat estimate, - - - - -	12,273	6	11½
To allowance of ten per cent. for contingencies, - - - - -	1,227	11	1
	13,500	18	0½

N. B. There is nothing allowed in the above estimate for land converted from the commons to a new river or drain, or taken from the inclosure in widening the present courses from the river or drains, nor for surveyors' salaries, nor any other kind of expenses, except what attend the articles set down, nor can the article of constructions, amounting to £3,610, be properly estimated till the proper plans for the execution of the respective articles are fixed, which cannot at present be done, which would take up a good deal of time, and if not executed, would be so much time and labour lost; nor is the deepening of the New Idle from Durtnefs bridges to Tunnel Pit, or the scouring or deepening any of the internal leading drains, considered in the above estimate, those being supposed works to be done by the present course of business.

ESTIMATE of the extra expense of the proposed new out-fall.

Now supposing a new sluice to be built at the proposed new out-fall near Waterton, at the same expense as the proposed out-fall and communication sluice at Althorpe, then
all

all the other articles will be equally necessary to both schemes, and the difference will lie in the cut, and as the cut will pass through other lordships, the value of the land must also be considered, which, if not paid for, other concessions must be made to the amount.

	£	s.	d.
Now, supposing this new out-fall cut to be a twenty feet bottom, and to rise two feet in its whole length from low-water mark of the Trent towards the north river, which is the least dimensions it can be supposed to have, the length being six miles and three chains, from Mr. Scott's measures, and levelling notes, I find it will contain 276,716 cube yards, which, at three-pence half-penny, is	-	4,085	8 10
And there will be cut twenty-seven acres of land, and near twice as much covered; but if the land cut is valued at £20. per acre, this will amount to	-	540	0 0
Suppose four road bridges, at £120. each,	-	480	0 0
And three communication bridges, at £60.,	-	180	0 0
And eight stop tunnels for the four intersecting drains, at £40. each,	-	320	0 0
Neat estimate,	-	5,605	8 10
To ten per cent. contingencies on the above,	-	560	10 10 $\frac{1}{2}$
Additional expense of the new out-fall,	-	6,165	19 8 $\frac{1}{2}$

J. SMEATON.

Austhorpe, 7th September, 1776.

DRAIN

DRAIN FROM KNIGHTSBRIDGE TO CHELSEA.

The REPORT of JOHN SMEATON, engineer, upon the expediency of carrying the outlet of the drain or sewer from the new street carrying on by Mr. Holland from Knightsbridge to Chelsea, into the brook below the turnpike road bridge, at the Cheshire Cheese, Chelsea.

HAVING carefully viewed and levelled what relates to the premises in question, it appears to me, that the surface of the water of the new sewer, where it is intersected by the drain running across the street that brings the surface and drainage water from a considerable track of distant grounds, is nearly upon a level with the bottom of the vaults of the adjacent new erected house, which is three feet four inches below the ground floor, or lowest floor of the said house; but as I found a point of the surface of the meadow opposite the said house, and between the street and the brook, to be elevated two feet eight inches above the surface of the drain, which point of the meadow is said to be covered several inches deep of water in time of great land floods coming down the said brook, it will follow that the ground floor of the said house is but little elevated above the surface of the flood water of the brook; while the area between the house and the vaults, as well as the vaults themselves, will be full three feet below the flood mark without; and hence it appears necessary to seek for some outfall more eligible and convenient than any that can be procured into the opposite part of the brook.

The fall that can be obtained by carrying the tail of the sewer down to an elbow, being the lowest part of the brook that lies open to the road about sixty or seventy yards below the bridge, is, according to my level taken, four feet nine inches, and which, being several yards lower down the brook than the point to which Mr. Holland levelled, agrees sufficiently near therewith to prove both, who made it four feet six inches, but being shewn the marks by the inhabitants there of the highest tides, and of the highest rise of the water in the time of the greatest land floods respectively; it appears that the highest tides rise at this place four feet six inches, and the land floods five feet, so that the highest tides will be within three inches of the bottom of the vaults, and the land floods three inches above them. The question that remains therefore is, whether, if the tail of the sewer be carried into the brook above the said brook at
the

the Cheshire Cheese, which being carried through grounds unembarrassed with houses, streets, or roads, will be more easily done, may not be sufficient for the drainage of these new buildings ?

The declivity of the surface of the water between the top of the conduit above the bridge, and the lowest point at the said elbow to which the level was taken below the bridge, was nine inches, but in time of great land floods from the obstruction and want of capacity, not only under the said bridge, but in the passages immediately leading to it, and from it, I can readily conceive that this fall at the surface of the water may at those times be doubled, and become eighteen inches ; and this being the case, if the outfall of the sewer was above the bridge, the water would, in consequence, be liable to be pent therein eighteen inches higher than before, that is, to the depth of twenty-one inches above the bottom of the vaults, and as this would put upwards of a foot depth of water into the areas between the house and the vaults, this would not only render the vaults useless, but cut off the communication between them and the respective houses, which would continue for such time as the land floods remained at the height above mentioned ; and though land floods, at that height, do not happen very frequently, yet, as such have happened, and may happen, in an undertaking of such extent and consequence, where even a misapplied apprehension or alarm of some of the first inhabitants might bring a discredit upon the whole, and where it can be but barely made safe when the tail of the sewer is carried to the most advantageous outfall, I cannot hesitate to recommend that it be so carried accordingly, that is, to the elbow of the brook, about sixty or seventy yards below the bridge, at the Cheshire Cheese, being the lowest point where it lies open to the road.

I would furthermore recommend, to prevent all annoyance by land floods, that provision be made for hanging a door at the tail of the sewers, and that the flood-waters brought down from the country by the intersecting drain first mentioned be not admitted into the sewer now recommended for building ; but as by the gaining this outfall the sewer of the building might be laid so deep as to go under the former, I would recommend the said intersecting drain to be tunnelled over it, and conveyed upon its own foot to its former or present outfall, because, if the country waters were to be admitted from the intersecting drain into the proposed sewer, it might in sudden downfalls so gorge the sewer with water, when obstructed by the brook's water at the tail, as to produce the same ill effect as would probably result from carrying the sewer into the brook above the said bridge as before stated.

I observe

I observe that the course of the brook below the said point recommended for the outfall of the sewer, is obstructed and narrow in several places, between that and the outfall of the brook at Ranelagh Water Gate Stairs, I would therefore advise, for further security, that the proper means be taken that the course of the said brook be kept properly cleansed and scoured.

J. SMEATON.

London, 8th April, 1778.

I would furthermore recommend, to prevent all annoyance by land floods, that provision be made for hanging a door at the tail of the sewer, and that the flood waters brought down from the country by the interlocking drain be not admitted into the sewer now recommended for building; but as by the raising the level of the sewer the outfall might be raised to such a height as to be under the town, I would recommend the said interlocking drain to be rammed over it, and conveyed upon its own bed to the outfall, because if the country waters were to be admitted from the interlocking drain into the proposed sewer, it might in sudden downfalls to gorge the sewer with water, which admitted by the brook's water at the tail, as to produce the same effect as would probably result from carrying the water into the brook above the said bridge we before stated.

I observe

CARLISLE

CARLISLE QUERIES.

Carlisle Queries, with the Answers.

Query 1st. Whether the bank made by Mr. Milbourn, in 1770, and continued ever since, has not, in a great measure, been the cause of the breach in Mr. Milbourn's ground in 1771; also, by throwing more water into the channel of the river, has not greatly contributed to the wasting of Mr. Milbourn's ground since that time?

Answer. It is impossible for me to say positively, that Mr. Milbourn's bank of 1770 was the sole cause of breaking his ground at the south-west end of the corporation wier, because other causes might concur, but the situation of the bank was so directly adapted to produce this effect, that unless some other sufficient cause had appeared, I should not have hesitated to have attributed the whole of the damage thereto.

A bank, extending more than half way across a valley composed of fine earth and loose gravel, the whole of which was, in great floods, overflowed with water, in the flanking position in which it stood and stands, must directly tend to waste the ground in the way it appears to have done, from the endeavour of the water again to spread itself after leaving the bank, and with an addition of rapidity arising from the contraction of its passage.

Query 2d. Whether the south-west end of the corporation's wier is not considerably higher than the south-east end, consequently, will tend to throw the water more to the east side of the river?

Answer. The south-east end, and indeed the greatest part of the length of the weir, is several feet lower than the south-west end; indeed, in its present state, it is so low as hardly to be considered as a wier or obstruction at all, which circumstance contributes very much to keep the current to the east side, but its sloping position upstréam, like the former wier (so far as its effects can amount to) will co-operate with the effect of Mr. Milbourn's present bank, tending to spread the water against the west border of the river.

Query 3d. Whether the corporation's present wier be not in as good a situation as the old one, and will do as little damage to Mr. Milbourn's grounds, if Mr. Milbourn neglect to put in defences to his ground?

Answer. If the wier were again rebuilt in its old position, it would be attended with every ill effect of the present one, as relative to Mr. Milbourn's grounds, with this very bad one in addition, that to raise the water into the corporation's mill leet (or dam, as here called) it must be raised just so much higher than the bed of the river at that place, as the bed of the river there is lower than the bed of the river in its present situation; it would therefore act more forcibly on Mr. Milbourn's grounds, and create a greater necessity of making defences, unless, by way of compensation, Mr. Milbourn removed his bank, and restored every thing to the situation of the year 1770 before his bank was raised.

Query 4th. What quantity of water will be sufficient to supply the corporation's mill in its present situation and structure?

Answer. The Barrow, in her present situation and structure, I find is effectually worked with a quantity of water amounting to 600 cube feet per minute.

Query 5th. Whether the waste in the Brumel and Barton's bleach field would be of any material service to the corporation's mills?

Answer. The waste at the Bleach field or Stampery amounts to three and a half cube feet per minute, which is less than $\frac{1}{176}$ part of the above quantity, whose effect cannot be perceived in the working of the mill.

Query 6th. Whether there is not more than sufficient at Milbourn's sluice to furnish his mills with water, on their present construction?

Answer. In the state in which I found the river, it afforded 2560 cube feet per minute, down to the corporation's, and Mr. Milbourn's dams, besides a quantity that overflowed the corporation's wier, and went down the channel of the river; but from the best information I can collect from the minutes of those who took measures thereof during the drought of last summer, it afforded full 1300 cube feet per minute; if therefore 650 cube feet were constantly taken for the supply of the corporation's mills, as leakages and evaporations will unavoidably happen, and they appear clearly to have
the

the first right of being served, there will still remain 650 feet for Denton mill in the driest seasons, which, as it appears, will render it equally capable of working one wheel abreast.

Query 7th. Whether you think it would be prudent in the corporation to purchase those fields of Mrs. Lind's, and take in the water at Rocky Bank?

Answer. If the corporation could purchase Mrs. Lind's lands at a fair valuation, they lie so that sometime they may be of use; but as I think the corporation cannot safely waive their right of attachment of a wier upon Mr. Milbourn, the disagreeable circumstances resulting from that, as also from the partition of the water, would equally remain.

Query 8th. Whether the tucks were not necessary to preserve the mill race, and not to injure Mr. Milbourn's grounds?

Answer. A defence is necessary where the corporation have made the tucks, and as they are in the mode of the country, I apprehend they are not under obligation to find a better, but in my own practice I recommend defences made parallel to the stream; I do not see they have any tendency to injure Mr. Milbourn's grounds in the position they stand.

Query 9th. Whether the abutment made at the high sluice is not absolutely necessary to prevent the water race being choaked with gravel?

Answer. I apprehend a work of this kind to be absolutely necessary.

Query 10th. Whether can the corporation's wier be more properly placed to do less damage to Mr. Milbourn's ground?

Answer. I do not see that it can, without the risk of producing fresh damages, fully adequate to what are likely in its present situation.

Query 11th. Whether the bank, in Mrs. Lind's ground, be not lower than Mr. Milbourn's bank, and necessary to prevent the ground from being overflowed, and the mill race destroyed in time of floods?

Answer. This bank appears to be a full foot lower than the opposite one of Mr. Milbourn's; in the present situation of Mr. Milbourn's I apprehend it to be expedient as a security, though perhaps not positively necessary; but in my opinion it would be much better for the prevention of damages to all the lands, if all the banks were away, and the river suffered to take its free course over the whole surface of the valley, as it did before the year 1770.

J. SMEATON.

Carlisle, 1st November, 1781.

THANKS

THANKS EMBANKMENT.

The **REPORT** of JOHN SMEATON, engineer, upon the practicability and expense of embanking a track of mud lying in the bay before the House of the Honorable Captain Graves, at Thanks, upon the river Tamar in Cornwall.

THIS track of soil, consisting of twenty-five acres, according to the admeasurement, lying directly in front of the mansion house, and betwixt that and the beautiful river Tamar, though it affords an addition of prospect when it is covered with water at high-water spring tides, yet being imperfectly covered at high-water neap tides, and at all times deserted and left bare for the greatest part of the interval between tide and tide, it must upon the whole be considered as an object very desirable to be converted into a different appearance. I therefore apprehend the value thereof as a piece of rich meadow is not the whole of the consideration in the present case; if it were, I could not advise, along with the certain expense that must attend the undertaking, to run the risk of its success.

A strong embankation against a large tide river, to hold out against the greatest extremes of winds and tides without any other foundation than a bed of mud, so soft that it is impracticable for a man to make his way over it, and in all probability the deeper the softer, may be reckoned among the extreme cases of practicable embankations; however, I look upon it in the present case, there is so great a probability of success, that if Captain Graves shall think proper to hazard the expense, I shall not be unwilling to risk my reputation as an artist upon it; the present and previous question therefore is, what the probable cost may be; and having considered and made my own suggestions as to the mode of execution, and regulated the measures by the plan and section put into my hands, and having carefully computed every article, the sum total in materials and workmanship, exclusive of temporary damage or spoil of ground for the obtaining matter from each side, and exclusive of any charges that may arise by supervisal thereof, will amount to £1193, which call £1200. If, therefore, the purchase of this piece of ground as meadow is worth £1200, I must advise Captain Graves, for the sake of the ornament, to stand the risk, and whenever the execution shall be resolved on, I shall be ready to prepare the proper plans and sections, and lay down the mode of proceeding that I would advise to be pursued.

J. SMEATON.

Austhorpe, 15th May, 1778.

COQUETT

COQUETT DAM.

(See plate VI.)

EXPLANATION of the design for a dam for the iron works upon the river Coquett, with directions for putting the same in execution.

Fig. 1st. is a general plan of the whole dam, with its land walls and conduits.

A B C D E F G—Shew half of the body of the dam, and the south land wall, as it will appear when completed wherein.

A B—Shews the sloping caping.

C—The rough setting, or continuance of the slope.

D—The rubble sloping apron.

E F—The caping of the dam's end land wall.

G—Rough setting within the caping, which, together with the caping of the return walls, is to be sloped upwards towards the land, in order to throw the stream as much as possible from the land.

H—The start and collar of the draw-shuttle, for closing or opening the conduit of the south-end wall at pleasure; the dotted lines shew the direction of the conduit.

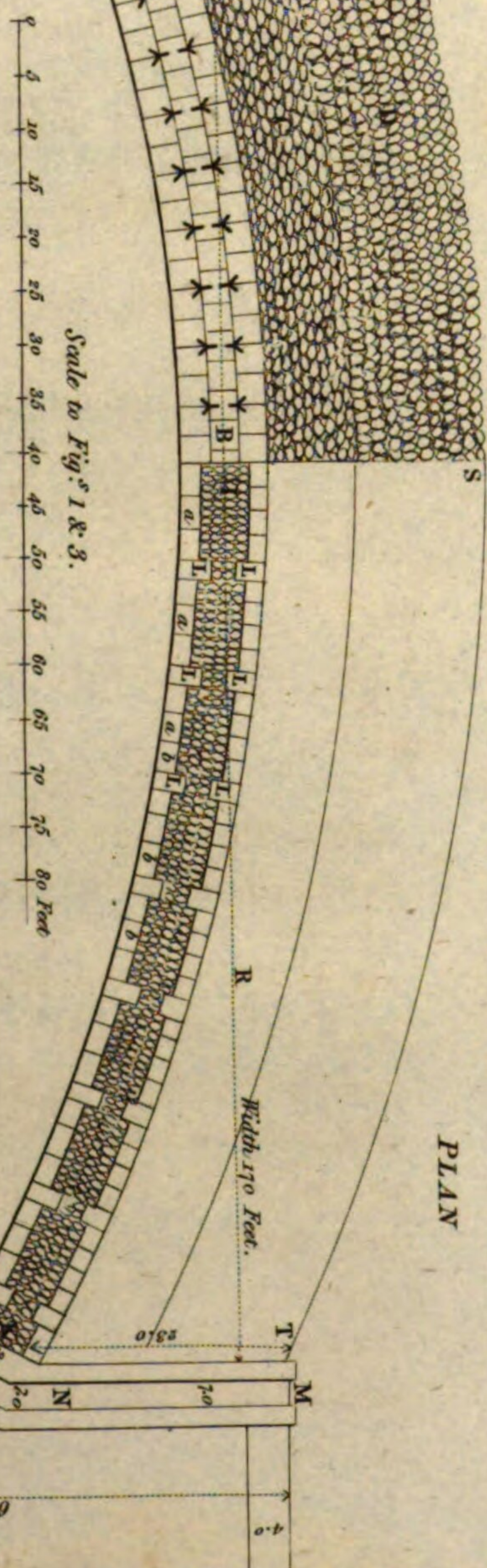
I K—Shew half the body of the dam, as it will appear when got a course above the ground course, or set-off, wherein

L L—Shew the disposition of the Tyes Bond-stones, or Headers, after every three stretches; and N. B. The headers are disposed, not over one another, but in the intermediate spaces, so as every third course to come somewhat about the same perpendicular again. They are to be snapped off at the inner end, to prevent the water in case of flood, while going on, from taking so much hold of them as to turn them up.

a a a, &c.—Shew trenails in the ailer of the down-stream courses, which will be more particularly explained, and

b b b b,

Fig. 1st



DESIGN FOR A DAM UPON THE RIVER COQUET.

Fig. 3rd End Elevation.

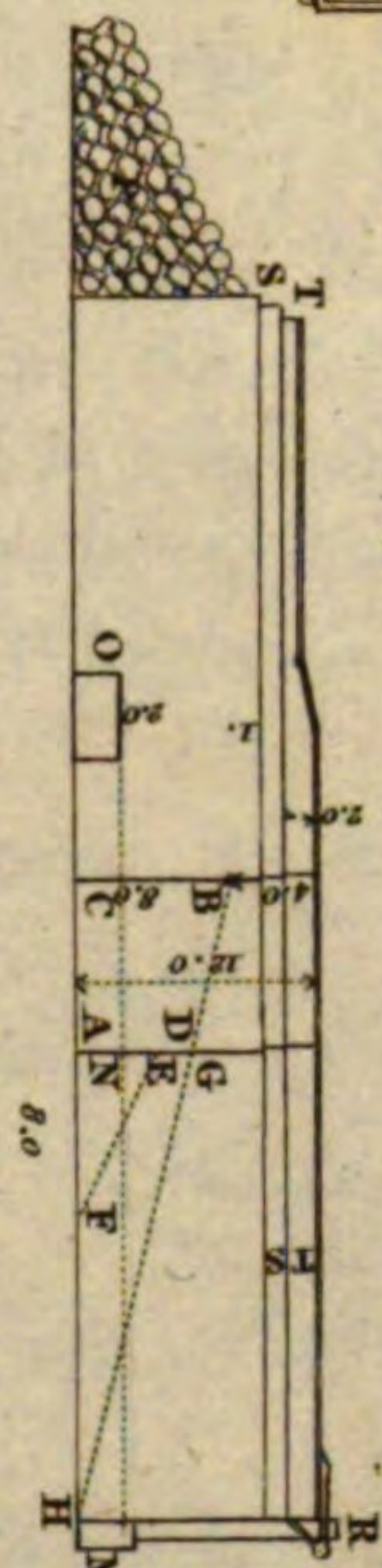
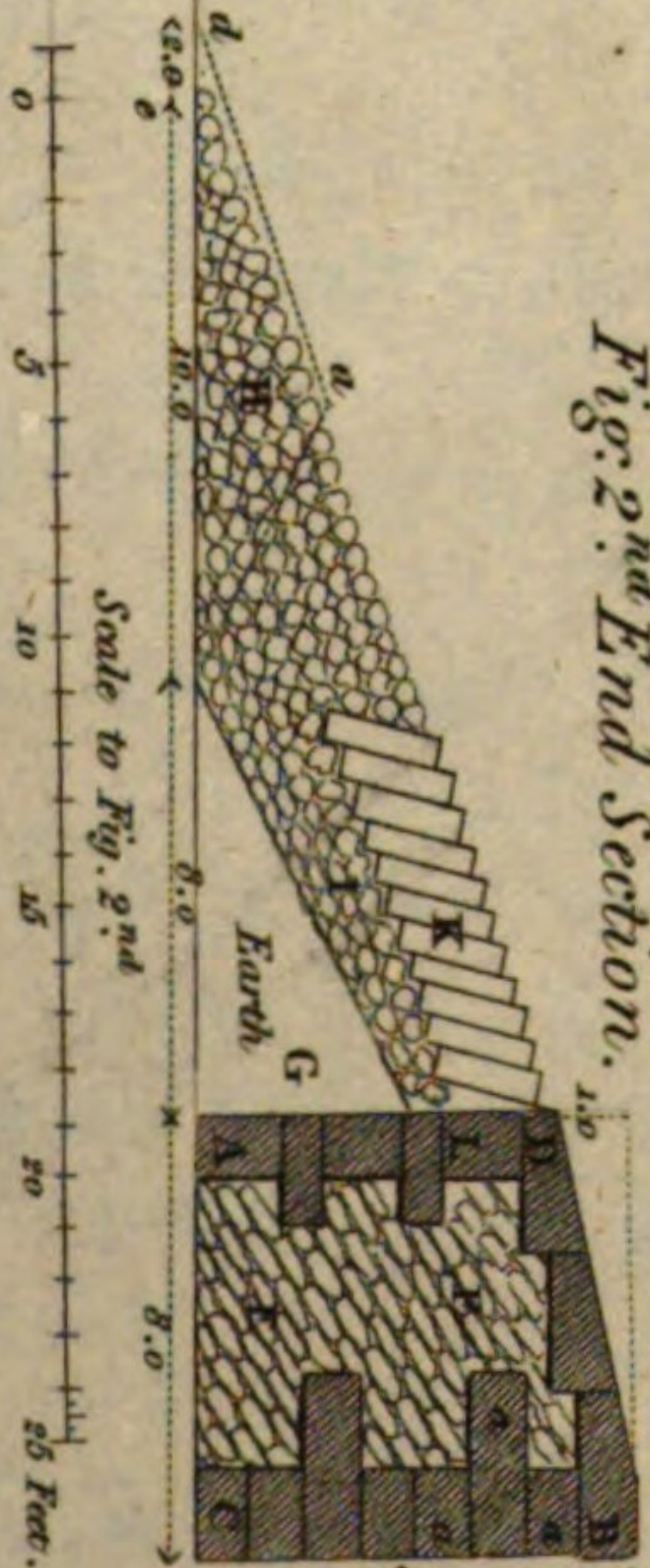


Fig. 2nd End Section.



FISHING DAM AT LUMLEY. page 333.

Fig. 5th

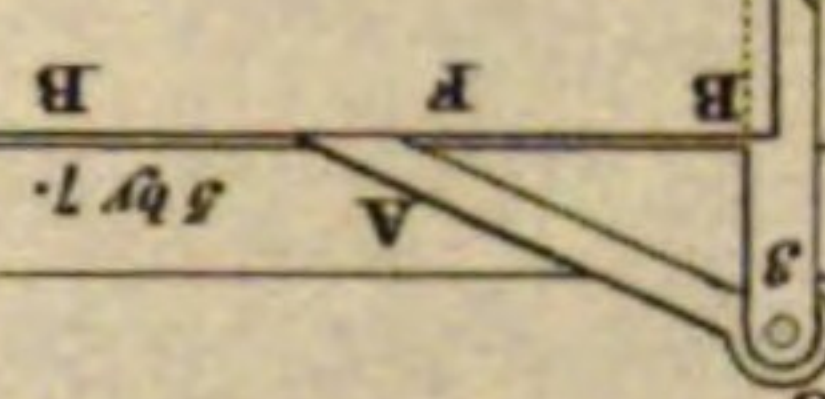


Fig. 4th

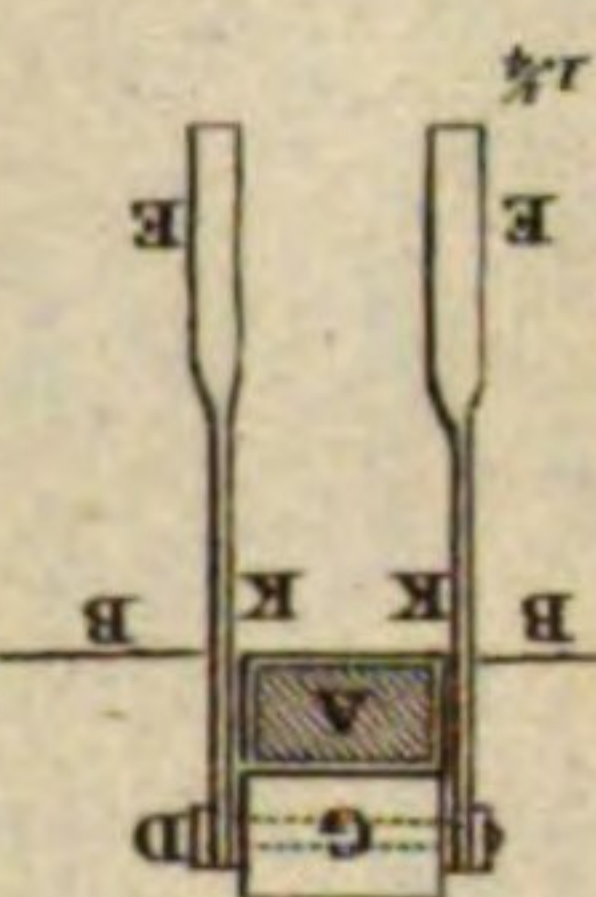


Fig. 8th

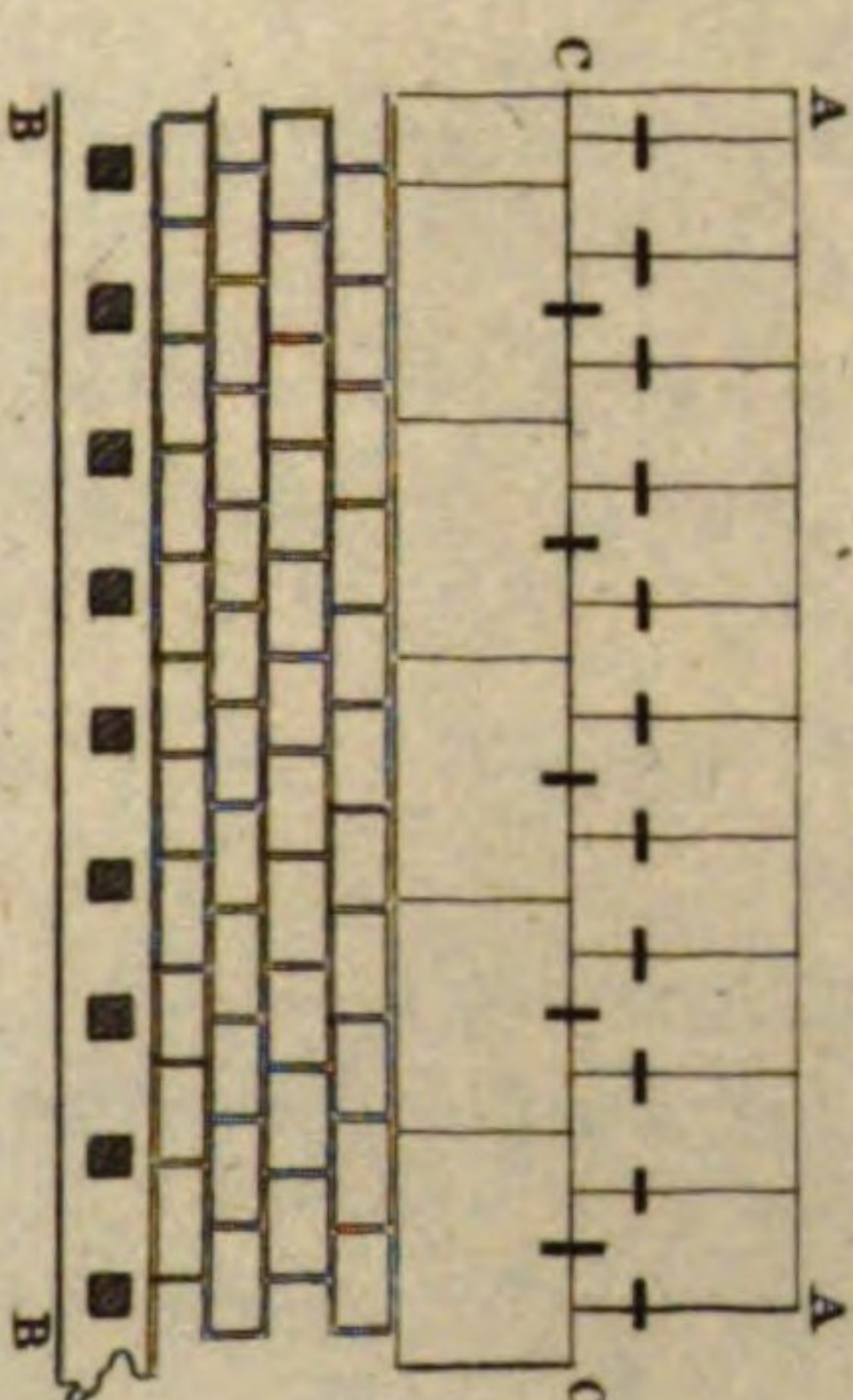


Fig. 7th

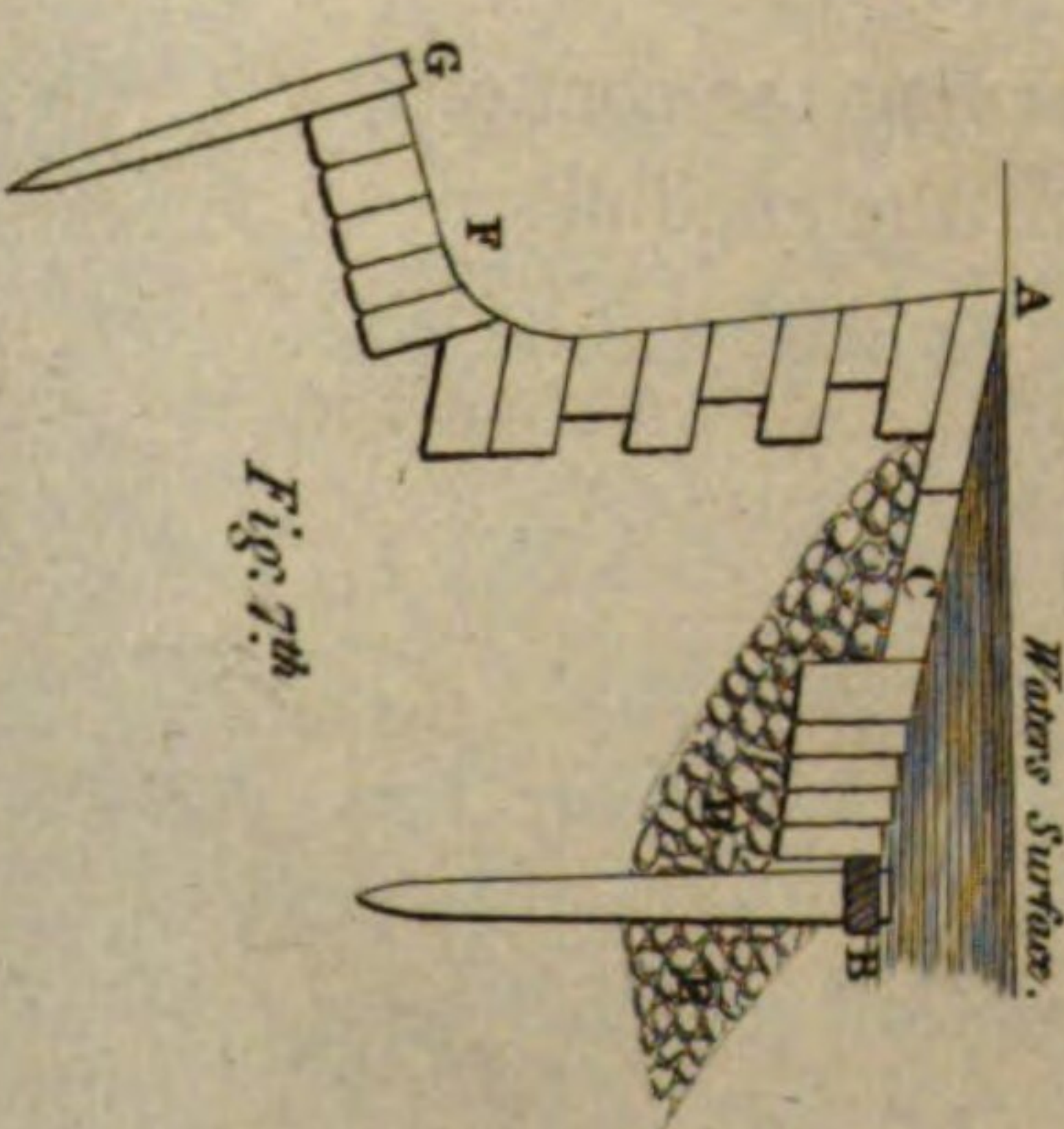
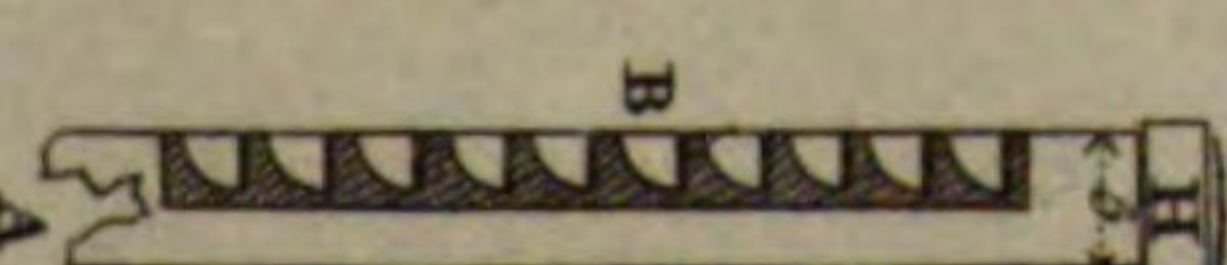


Fig. 6th



Fig. 7th



b b b b, &c.—Are wedges in the inner joint of each course, likewise to be more particularly explained. The space between the two ailer faces to be backed with rubble, disposed as will be also further more particularly explained.

M—Shews two projecting cheeks of stone, containing the grooves for the shuttles, and N. B. All the parts of stone, against which the shuttle will rub or slide, should be made dry, and tallow burnt into the pores of the stone with a hot iron, which will preserve not only the stone but the wood from wear, and to make the tallow lead in the better, and strike deeper, it will be proper first to oil over the surface with linseed oil.

M N O—Shew the conduit before it was covered.

R—A slope of earth to prevent the water from penetrating into the ground joints of the body of the dam, and

S T—Mark out the extremity of the rubble upper apron.

P Q—The corners, filled with slopes of rough rubble to prevent the eddy water from returning and affecting the land.

Fig. 2d. is a section of the body of the dam, to a larger scale, wherein

A B—Is the solid body of the dam, to be firmly built with masonry.

B C—A section of the down-stream face.

A L D—A section of the up-stream face, and D B that of the caping.

E F—The rubble backing laid in sloping courses, as well as the nature of the materials will admit, to what is represented, and to be worked in very solid, the utility whereof will be further explained.

a a a—The trenails in the down-stream courses of ailer to be further explained.

G—The slope of earth.

H I—The

H I—The rubble sloping apron to protect the slope of earth from being washed away by the water, and to conduct heavy floating bodies from injuring the body of the dam or caping.

K—Rough setting, the better to resist the action of floating bodies.

D L—Upright cramps to every other piece of caping.

N. B. The dotted lines, a b, a c, denote the mass of rubble used for a catch dam, and a d the slope of earth thereto.

Fig. 3d shews the upright face of one of the dam's end walls, or land-walls, being to the same scale as fig. 1st, wherein

A D B C—Shew the section of the body of the dam,

E F—The slope of earth.

G H—The rubble slope.

M—The projecting cheeks for the shuttle to slide in.

O—The tail of the conduit, appearing broader on account of its oblique section by the face of the wall.

M N O—The conduit, defined by the dotted line.

M R—The shuttle starts and cheeks of the collar.

P—The filling up of the angles with slopes of rubble.

S T—Set off on the face of the wall of six inches each, the backside is also set off as represented at E F, in fig. 1st,

Fig. 4th is the plan, and fig. 5th the upright of the top of the start of the shuttle, wherein the said letters refer to both.

A—Is the start of the shuttle.

B B C—The

B B C—The face of the wall.

D E—The cheeks of the collar cramped into the wall.

D F—The struts for keeping it firm and steady.

G—The roller, whose axis being released by taking out the bolt, the start is at liberty to be taken out.

H—A hoop to keep the head of the start from splitting.

K—Is an indenture into which a short round being laid will serve as a prise to the lever.

Fig. 6. is the upright face, and fig. 7. is a profile section of the start and cast iron rack, to which apply an iron gave lock or lever to draw the shuttle, wherein both refer to the same letters.

B—Denotes the teeth of the rack, to support which, they are to be cast solid with teeth, and let into

A—The start, and are fixed and prevented from drawing by the ears.

C C C—

H—The hoop at top.

DIRECTIONS FOR THE EXECUTION.

There is not a more difficult or hazardous piece of work within the compass of civil engineery than the establishment of a high dam upon a rapid river that is liable to great and sudden floods, and such I esteem the river Coquett, and such the dam here proposed to be erected; and when it is considered, that the performance of every part of the intended works depends upon the firmness and well-establishment of the dam, and further considered what loss, disappointment, trouble, and vexation will attend a failure thereof, especially in the winter season, when such a misfortune is more likely to happen than at any other time, it will readily be granted that too much care and circumspection

cumspedition cannot be used in putting the design here proposed into execution, and which, if duly and carefully attended to, will, in my estimation, not only be proof against all that can come against it, but may be executed without any material derangement from floods, while it is going on, and especially if begun and carried on at a proper time of the year, with a competent number of workmen.

The time of the year I would recommend to begin is as soon in April as the weather appears to be tolerably mild and settled, which generally happens about the middle of that month; and as the distance between the land stool walls on the upstream side of the dam is proposed to be 170 feet, equal to the width of the river at the water line, when raised to the height of the dam, the foundation pits will be required to be sunk in the slopes of the banks, so that they will be defensible from the river in all middling speats, and this part of the work may be going properly on before the surface of the river is reduced to its low dry weather state. I would therefore advise, that the land stool walls, with their respective conduits, (which will be fully sufficient for conveying the current of the river in its ordinary dry weather state) be first not only established, but completely finished before the work of the body of the dam is begun; and this direction is the more necessary to be observed, because I have known in several instances, for want of attending to this, that the river has made a new course between the land or dam's end walls, and the main land; so that the walls should not only be raised to their height, and capped, but rough setting, such as is represented at the south land stool at G, should be completed.

It is to be noted, that the conduits being supposed two feet square in the clear opening, are to be built with well-jointed asler; and in case the rock should prove too tender, jointy, or uneven, which will probably be the case, it will be proper to inlay well-hewn floor stones of six or eight inches thick, and at least three inches broader on each side than the conduit, so that the side walls may step or tread thereon, and the covers must also be of single stones, to reach across, similar to the floor stones, and the whole jointed with good water cement of pozzelana mortar, such as hereafter will be described. The dam's end walls being thus substantially constructed, and made ready to receive the river's current, the water is to be turned through the conduits as follows. Let a part of the mass of rubble stone be deposited as represented at H, fig. 2., so as to form a kind of bank $2\frac{1}{2}$ feet high, and sloping each way, and arching conformable to the base of the dam, before which deposit a quantity of earth, which, by treading or working, will stop the water and form a catch dam so as to turn the current of the river through the conduits. And as this catch dam, as to the

the rubble part of it, will, in fact, be so much done towards the general construction, it will be proper at first to give it a good base, and slope downstream, for it will thus be enabled to resist a speat without material derangement, which is always to be expected and provided against during the going on of the work : by this means, and the aid of a few sods, and earth to prevent the water reverting, after it has passed the conduits, the whole area, whereon the dams are to be built, will be laid dry.

The outline of the downstream side of the dam is then to be traced out by a radius of 170 feet, (which may be done by forming together a number of small slips of deal, like pantile laths, having men to support them at proper distances from the ground), and the upper side by a radius of 178 feet. The stony bed of the river for the breadth of the aisler respectively forming the upstream and downstream face of the wall, is then to be reduced into level stretches, not all reduced to the same level for the whole length of the dam, or breadth of the river ; but as far as each can be conveniently pursued upon one level, rising or falling by a step from one level stretch to another : and the thickness or height of the aislers are to be so adapted, that they will all come to one level at the top of the first, or if need be, the second course, and then upon the downstream face you set off a couple of inches ; but the upstream face wall is to be built perpendicular, without any set-off.

The whole ground bed of the aisler upon the rock must be laid with the best cement, and the front of every course upward, for at least six inches inward from the face of the wall must be jointed with the best mortar also ; but still better, if the aisler were wholly bedded therein from top to bottom.

The whole row of aisler in the ground course of the downstream side should be set and closed in before any part of the first row of aisler of the upstream face wall is set, and as the first row of aisler on the downstream side is carried on, it must be backed up upon a sloping surface, a little short of the upstream course up to the full height of the downstream course ; and the whole of that course being thus finished, and backed up, then begin to bring on the second course downstream, and the first course upstream, completing the backing upon a slope as before from the top of the first course upstream, to the top of the second course downstream ; observing always, that these slope surfaces be as well closed in, and laid as snugly and smooth as possible, with this intent, that when a fresh or speat comes down while the body of the dam is building, that the water may glide over it with the least impediment possible, by which means it will be subject to the least derangement ; and to the intent that

the water may affect the whole as equally as possible. A new course is never to be begun till the course preceding is completed, observing always, to keep the upstream face a course lower than the downstream; and every Saturday evening, or upon the apparent approach of rain in an evening, not to leave, if it be possible, a course incomplete in that situation.

As a flood going over the dam in an incomplete state is most likely to take down the aisler of the downstream face, by way of security and prevention, I propose that every other stone should be pinned down by an oaken or fir trenail of one inch and a quarter diameter, reaching through the upper, and at least six inches into the course below, and a fir wedge being moderately driven into the back side upper corner in each joint of the aisler, this will steady every stone between two of its neighbours that are trenailed down, and thereby the whole will become fixed, as it were, in one arched mass, and fast to all under courses. This trenailing may appear a good deal of trouble, as it is only meant as a temporary security, while the dam is building, yet as the hindrance will be nothing, provided additional people are appointed to this service, and the cost trifling in proportion to the damage that might otherwise be done by a single flood coming down during the course of the building, I cannot but strongly advise it; and as by this means, together with the former directions, the work will be carried on with perfect security, all that hurry and bustle will thereby be avoided, that alone renders the work considerably more expensive. The practice should be this: the holes in the course setting should be bored through before the stones are sett, with jumpers gaged to bore a hole $1\frac{3}{8}$ inch diameter, and after the stones are set, another person with a jumper gaged to $1\frac{1}{4}$ inch, continues the whole six inches deep into the stone below; which done, (a number of trenails being ready prepared of a sufficient length, and truly planed to an octagon formed from a square gaged to full $1\frac{1}{4}$ inch), and the leading end of the trenail being a little snapped off, to give it a clear entrance, it will easily drive through the upper stone having a hole of $1\frac{3}{8}$ inch, and the angles of the octagon left on will, by driving, compress and fill the under hole pretty tightly, which the swelling of the wood by wet will soon render still tighter; but as notwithstanding all care the jumpers may not all bore perfectly alike, nor the trenails planed up be exactly to the same gage, the under or entering end of every trenail must be split with a saw for about $1\frac{1}{2}$ inch, and an oak wedge of about $2\frac{1}{2}$ inches long, $1\frac{1}{8}$ inch broad, and about a quarter an inch thick at the head introduced into the slit, and then when the end of the wedge touches the bottom of the hole, the trenail, if not already jammed, will be effectually so, by the penetration of the wedge into the trenail; this done, the top of the trenail being cut off flush with the
upper

upper side of the stone, and then wedged somewhat kindly, the whole is made level, and the trenail prevented from drawing either above or below. I hardly need say, that the trenails should be made of clean stuff, free from knots, otherwise they will break in driving; but it may be necessary to say, that they should be planed up upon a parallel, and not made with the entering end smaller than the other; for every thing expected from this is done by the two wedges, and all danger prevented of their jamming improperly; it is also necessary to say, that they ought not to be driven by an axe, or any small round faced hammer, but by a flat faced iron maul, such as is used by ship-carpenters for driving their trenails. The whole that I have hitherto mentioned is easily executable by common hands: but the point that will require the most attention will be in the person that fits the stones to the courses, to mark out the holes of such as he proposes to be bored through, that when they come into their places, the holes of the upper may miss the joint of the under; but if this is thought too great a task, if every bored stone is about four inches out of the middle of its length, it will always miss a joint, by changing the other side up when found necessary. The upstream ailer course will need no trenails, being abutted upon the rubble, and defended by lying so much lower.

As the ground course upstream is carried on, it should be immediately gently rammed behind with earth, and the sloping apron of earth gradually brought on as the courses are advanced; and the rubble backing should also advance proportionably with the main body between the catch dam and this slope of earth.

J. SMEATON.

Austhorpe, 13th September, 1776.

Face mortar for downstream ailer.

To two bushels of slaked lime in flour sifted.

One bushel of Civita Vecchia pozzelana.

One bushel of good sharp sand, beat the whole well together till tough like a paste.

Face mortar for upstream ailer and backing the joints of downstream.

To two bushels of common mortar prepared with its ordinary quantity of sand measured when wetted up, add

Half a bushel of quick lime in flour sifted, and

Half a bushel of Civita Vecchia pozzelana sifted, the whole well beaten till tough, like a paste.

Mortar

Mortar for the backing, or inside rubble work.

To three bushels of common mortar measured, when wetted up, add

One bushel of quick lime in flour, when sifted, and thrown in by degrees, with the necessary addition of water, upon making it up for use, beaten well.

The conduits to be jointed with downstream face mortar.

The land walls below the level of the dam's caping upstream, of upstream face mortar.

The land walls to be one foot above dam's height for ten feet below the dam's crown, and three feet high at the tail of downstream mortar, all above of upstream mortar, the backing mortar as above.

J.S.

FISHING

Mortar

FISHING DAM, AT LUMLEY CASTLE.

See pl. VI. figs. 7, 8.

ON viewing and examining the dam at Lumley, I find its original construction so very bold, and, as I should esteem it, unsafe, that it surprises me how it has stood so long. The breach made last winter is now so far stopped as to pen the water to its usual height. By way of further security, I would advise to fill the pool-hole below with rough quarry stone thrown in, and also to form a sufficient slope on the upper side in the same manner, and then to make good the wall and penning at the foot, in the way that it has hitherto been; for, as it would cost a very considerable sum of money to build a new dam there, upon solid principles, I do not see that any thing can be done better with it, than to repair it as it stands; and as it has stood a great many years, notwithstanding the natural weakness of its construction, it is very possible, with proper repairs, it may continue so to do. The greatest deficiency that is experienced, arises from the capping being taken off by the ice; as the top is composed of stones of very middling size, they are to be kept down by laying a boarding of brush-wood upon them, which brush-wood is kept down by laying stones thereupon; when this fails, the wall of the dam is liable to be taken down. The most likely way to preserve the dam will be, therefore, to cap it in a more effectual manner, and I would recommend the method described in the sketch; fig. 7, pl. VI. being a section, and fig. 8. a plan of a portion of the dam, wherein A A A is the front or delivery nose of the dam, B B B a half tree fixed with piles, at about ten feet up-stream of the front, and to be fixed as low as it can conveniently be got in a dry season in the summer, suppose $2\frac{1}{2}$ or three feet below the full dam's surface; instead of the brush, I propose long stones of eight or nine inches thick, A C laid sloping towards the half tree, the longer these stones are the better, but they should not be of less length than three feet; these to be cramped, every other stone, to long deep setters, and joggled every stone to its neighbour, as shewn, fig. 8. The rest of the space between the deep course of large setters and the half tree, to be penned in with rough pen stones, and the whole to be supported by rough stones as shewn at D, and the slope E in the section, these to be thrown in after the piles of the half-tree are drove; F shews the present penning or apron supported by the piles G.

J. SMEATON.

Austhorpe, 15th May, 1777.

N. B. A part of their capping may be done annually, and the rest supported with brush-wood till the whole can be executed.

KINNAIRD

KINNAIRD ENGINE.

The REPORT of JOHN SMEATON, engineer, upon the powers and improvements of the engine of Kinnaird, &c.

HAVING received the following propositions or message, from the Carron Company, I proceeded to an examination of the premises. The message is as follows :

After Mr. Smeaton has viewed the present engine, with the situation of the house, and considered any other facts he may think necessary to be informed of, the company wish to be advised which of the following modes they should pursue, in order to be fully able to command the water, and fulfil their contract and after-agreement, with Mr. Bruce.

1st. Would Mr. Smeaton advise the increasing the powers of the present engine, and to sink it to the Cox-road coal, and run another back mine ?

2dly. Would he advise the present engine to stand where it is, and erect a small additional engine upon No. 10. pit ? and if that could be done, and leave room in the pit, (which is nine feet diameter), to draw the coal, and save the expense of sinking another pit ?

3dly. Or would Mr. Smeaton advise the erecting a new engine upon No. 10. pit, or elsewhere, of sufficient powers to draw all the water from the depth of fifty fathoms ?

N. B. The bore of the present lift is $14\frac{1}{4}$ inches, and it was imagined it would require another bore of eight or nine inches to command the water ?

Having, in consequence of the above, examined the premises, and made my own observations, and having also read a printed tract, entitled, " Memorial for the Carron Company, 23d Jan. 1777," and considered the plan thereto annexed, my opinion upon the different articles is as follows :

Answer to the 1st.—In perusing the printed paper, I find there has been much alteration, whether the engine that has been erected at Kinnaird, either in its former state, with

with a cylinder of $52\frac{1}{2}$ inches, or as at present, with a cylinder of sixty-two inches, was or was not of sufficient power to draw water from the depths required; now, as it may give some light into the whole of the matter before me, to clear this point, I will endeavour to do it before I proceed further.

I do not find that, in all the various reasonings about the power of this engine, regard has been had to any other circumstances than the diameter of the cylinder, and the diameter and perpendicular height of the pumps thereto annexed, so as to calculate what neat burthen is laid upon each square inch of the cylinder or piston's area, without paying any regard to the velocity of the engine's motion under such burthen, that is to say, to the number of strokes made per minute, and length of the stroke, without which it is impossible to calculate the quantity of water drawn to a given height, and without which all reasoning about the effect of the power of an engine, is like attempting to ascertain the capacity or content of a solid, by having only two dimensions.

In the course of my observations upon fire engines, through a considerable series of years, I have found engines calculated to carry a load, varying from under 5 lbs. to upwards of 10 lbs. to the square inch, those carrying a light burthen are expected to go with greater velocity than those carrying a heavy one; so that if an engine, carrying 5 lbs. to the inch, goes with double the velocity, or, as I call it, makes twice the journey per minute, to what is made by an engine whose cylinder is of equal area that carries 10 lbs. the effects of the power or business done will be equal, that is, the water actually raised from an equal depth will be equal. In the fire-engine, however, as in other machines, there is a maximum that without new principles of power cannot be exceeded; bad proportions of the parts, and bad workmanship, may make an engine fall short in any degree of what it should do; but which cannot be exceeded by the most accomplished artists.

Experience has, however, in some degree, directed discerning artists towards a medium, as to the burthen an engine should carry upon the square inch. The original patentees, from some of their first performances, laid it down as a rule to load the piston, so as but little to exceed 8 lbs. to the inch; but, on more experience, they diminished that load, and amongst the best articles of late years the practice has been to give them at or about 7 lbs. to the inch. Any of these will do, if the parts are properly proportioned, but, from a long course of very laborious experiments, I have fixed my scale near upon, but somewhat under 8 lbs. to the inch, including the raising the
injection.

injection water, which is a circumstance never brought into the question in the several computations mentioned concerning Kinnaird engine.

A pump $4\frac{1}{2}$ feet below the pavement of the Cox road coal appears to be 104 yards below the delivery drift of the engine pit, which, to allow for one or more cisterns, call 106 yards; now, according to my scale, an engine of sixty-two inches cylinder, will work a pump 106 yards in height, of near upon $14\frac{1}{2}$ inches, the present pump being but $14\frac{1}{4}$ inches, will, therefore, be under the proper load. An engine also so loaded will go $10\frac{1}{4}$ strokes per minute of eight feet two inches each, that is, it will make a journey of $83\frac{2}{3}$ feet per minute; whereas the present engine, in the condition I found it the 2d September last, was going $11\frac{1}{4}$ strokes per minute, of six feet each, and then taking down its water, there being near twelve fathom water in the pit, occasioned by a preceding stoppage to put in a new set of larger pumps for the ground column: now, though it made $11\frac{1}{4}$ strokes per minute, yet they being only of six feet each, its journey was no more than $67\frac{1}{2}$ feet per minute, which is less than $83\frac{2}{3}$ by near upon one-fourth part of the present performance; and as the upper tier of pumps was no more than fourteen inches, we may safely lay it down, that the effects of the present engine may be improved without augmenting the powers, in the sense I apprehend is meant by the question (that is, by putting in a larger cylinder and pumps in the proportion of four to five), that is, by one full fourth of the present performance, and yet take the water from the pavement of the Cox road coal. This supposes also, that all the water is let down to the bottom of the Cox road coal, and then drawn up again, whereas the water being detained at its present random of the engine pump foot, it is probable, that a small bore would draw the water from the Cox road coal; and also in running a back mine underneath the former to the verge of the boundary of the estate, which is all I apprehend can be expected from the company in literal performance of their after-contract, as they cannot be required to find the main coal within the boundary of the estate, unless it were there; and if the company have nothing further in view than the literal accomplishment of their contract, this seems not only to be the best, but the only way by which it can be done.

In comparing the performance of an engine of sixty-two inches cylinder, such as I have stated it when improved, with what it performs at present, or probably ever has done, it may possibly be inferred, that the engine at Kinnaird has always been defective in construction, size, or strength, to what it ought to have been in conformity to the lease; but here I must remark, that if it was not defective in any of those respects,
according

according to what was deemed the best mode of practice at the time it was erected, it could not be incumbent on the company to perform what was then not known, as no one could, or can foresee what improvements in these machines could, or actually have been made; and as I date the improvements mentioned when brought into the field to so late a date as the beginning of the year 1774, this is long posterior to the erection of this engine.

Kinnaird engine appears from the first intended to work a fourteen inch pump, which is a larger size than has been commonly calculated upon, to wiew a coal whose quantity of water was unknown: twelve inches in this case has generally been deemed sufficient.

A cylinder of $52\frac{1}{2}$ inches to work a pump of eighty yards in height, which appears to be sufficient for winning the main coal at the place where the engine now stands, and of fourteen inches bore, would lay no more, including injection water, than $7\frac{7}{8}$ lbs. per square inch upon the pistons, which is very nearly what I have since proved by experiments to be the best; and if a $52\frac{1}{2}$ inch cylinder were fitted to this work, as we may well suppose in the interval between Martinmas, 1760, when the lease commenced, and the 31st of December, twelve months following, when the visitors ordered the company to go down to the Cox road coal, and there run a level mine to cut the main coal to the dip; I say, if in the space of thirteen months, a $52\frac{1}{2}$ inch cylinder were fitted to this work, it was very natural, and I look upon it at the time adviseable, to try how far they could go with this cylinder, since no one can say with certainty what is in the bowels of the earth, either of strata or water, till they are pierced; and the rather, because if they then had in prospect, what I am informed was really the case, that they should take in a considerable feeder at the middle of the pit to the cistern of the upper column of pumps, then they had a probable chance to go down with a pump of less size to the pavement of the Cox road coal; and a less pump was actually put in, and there continued till the new pump was put in (as I am informed) the last summer. Now, if the upper column of pumps were fourteen inches, and a lower column of thirteen inches had been found sufficient to have drawn the water from the Cox road coal, these would have laid no more burthen upon the piston than $9\frac{1}{2}$ lbs. upon the inch, which is yet considerably under the limits of the burthen, which before that time I had seen in use, and at that time, so far as I know, no man had proved what was best. It was, however, then commonly known, that the engine under this load would go slower than if the burthen were lighter; but for ought that then appeared, or was known, it might be expected to draw more water than the same cylinder would have done, if fitted with twelve-inch pumps, which, from the Cox road coal, including injection, would have laid no more upon it than $7\frac{7}{8}$ to the inch and which, as already observed, speculatively

culatively considered, might be deemed at this time an adviseable power to attempt the winning of a colliery whose quantity of water is not known; and had the strata laid as supposed in the after-agreement of the 31st December, 1761, the work done accordingly, and the water grown easier, by continuance of working, as frequently proves to be the case, then there had been no reason of complaint of the insufficiency of the engine.

It happened that in the year 1769, curiosity and observation (being in these parts) led me to take a view of Kinnaird engine, which was then working with the fifty-two and a half inch cylinder; the minutes of this view are now before me, and it appears to me that this engine was doing as much work in proportion to its size of cylinder, as the generality of engines at that time did, of which I examined a good many, being then preparing for my own experiments.

This engine, however, as I understand, by unloosing more water, was afterwards overpowered, and the Carron company did then what is usually done in the case, put in a larger cylinder, increasing it from fifty-two and a half to sixty-two; the pump being too great a load for the smaller cylinder, remaining as before; the effect of which alteration would doubtless be by diminishing the load upon each inch of the piston's area, to increase the velocity of the motion, and thereby with the same pumps to draw more water; and which water having since again increased, the sixty-two inch cylinder is now in want of a further increase, or of improvements that may be tantamount. It, however, may now be made a question, whether the building was originally made so as to be likely to be strong enough for such an increase of power, because, if it was not, the Carron company must be allowed to be blameable otherwise, in building an engine incapable of a greater power than that originally designed, when it frequently happens that an increase of power in these cases is wanted.

In this respect, as I find the beam wall above five feet thick, and the other walls proportionable, I conclude it built with intention, if occasion required, to receive a greater cylinder than the original one of fifty-two and a half inches; its dimensions are fully sufficient for a cylinder of the size put in, and of supposition of the foundation being good, I should not scruple to put in a cylinder of seventy inches; a considerable settlement has however happened in the beam wall directly under the working beam, since the putting up of the sixty-two inch cylinder; the question is therefore, whether this sett has happened through want of dimensions, or insufficiency of the work, or from some other cause?

As I am informed, some feet under the beam wall there is a stratum of sand which, though sufficiently compact to bear weight, will not bear the least oozing of water, if it can get loose, as is commonly the case: this stratum I understand was sunk through in sinking the little staple pit for the injection pump; now, in wet seasons, a very small drainage of water from this stratum of sand into the staple pit will bring particles of sand along with it, and by continuance of the same for years, though almost imperceptible in a small space, is very capable of producing the effect now seen, and though it is probable that this would have appeared before this time, though the fifty-two and a half cylinder had remained, yet the greater the agitation caused by the larger cylinder, and perhaps wet seasons co-operating therewith, may of late have brought on this appearance in a greater degree; and it is an argument of the solidity wherewith the walls of this building have been raised, that the settlement is perpendicular, being in the middle under the beam, and near the staple pit, while the side walls at a greater distance, and less pressed, stand where they were built.

The properest way to put a stop to this evil, which, from the nature of it, above described, must be growing, will be to put into the staple a cradle or tub, close boarded, so as nearly to shut up the water, but effectually the particles of sand issuing from this stratum, and if need be to continue the boarding or sheeting on the side next the engine of the main pit. This effectually done, the settlement will go no further, but if it be not, recourse must be had to buttresses to discharge the weight and action of the beam sideways, which buttresses had best be founded near the surface, and if need be, supported by piles driven thereunder; it is impracticable to rebuilt the beam wall in a going engine, otherwise, if time would permit, an arch might be cast over the space liable to settle.

Furthermore, as it appears that the plan of the engine is such as to be capable of having as many boilers, and of as large size as in event might be wanted; in this respect also it is adapted to an enlargement of the powers, and though it is by no means such a construction as I should now recommend, yet at the time of the erection, things appear to have been done and disposed in such a method, as was most generally approved; in short, though the Carron company do not seem to have been sparing in the execution of such things as from time to time have appeared for the best, yet they seem to have been particularly unfortunate in receding from the first proposed situation of the engine; for had they persevered in getting through the first difficulties of that situation, every thing after would have become easy, and many heavy expenses, and many disappointments.

ments avoided. Having now dispatched the immediate subject of the first question, as well as what naturally arose out of it, I proceed to consider the subsequent.

In answer to the 2d and 3d questions, which I shall take together, because they both of them seem to imply the giving up any idea of a specific literal performance of the after-agreement of the 29th of December, 1761, in respect to the sinking of the Cox road coal, &c. and to put the matter from what has turned, upon what is best now to be done, in order to win out of the Kinnaird estate as much coal as can be got out of the main coal, and such of the upper seams as it may seem eligible to get.

It is now stated to me, that the pavement of the coal, at the pit No. 10, lies ten feet below the foot of the present engine pump; it appears therefore necessary in order to get the coal there, to erect an engine of some kind at the pit No. 10, and the question is, whether a small engine, with pumps of eight or nine inches, to draw such quantities of water as cannot be commanded, in point of level, by the present engine, or at once to erect an engine of such construction, power, and size, as shall command the water of the whole field at that place? and I cannot hesitate in saying, that I look upon it to be the ultimate interest of the company, under the circumstance of waiving all other agreements, to build a new engine at pit No. 10, that shall at once be likely to command the water of the whole field.

To begin a work with such a power as is generally found to be competent, though from unforeseen accidents it afterwards proves to be otherwise, this must be looked upon among the number of uncertainties that attend these affairs; but now that the field is in a great measure explored, and the quantity of water investigated, to erect any thing that has not the probability of being fully competent, would be unpardonable. It is stated that a nine-inch bore may be wanted in aid of the present engine: to work this with proper effect at No. 10 pit, will require a thirty-seven or thirty-eight inch cylinder to be erected new, with a house, and all its furniture; but to do this work, and all that I found doing at the present engine will be done by a sixty-five inch cylinder, properly constructed at No. 10 pit; yet to provide for all contingencies that can reasonably be expected, I would advise the company to put on an engine of the first rate, viz. an engine of seventy-two inches cylinder, which will work pumps of seventeen inches bore, and draw one-fifth more water than the last-mentioned engine, and in case there should be no increase of water beyond the present, will do its business in less than fifteen hours per day: the great advantage of having time to spare is well known.

Much

Much in cases of this kind depends upon the estimates of expenses, but to make an accurate estimate of two fire engines would of itself take much time, and when done, the balance of the account would be involved in the uncertainty that would attend the altering and putting the present engine into a good and durable way of performing its duty. I must therefore, at present, content myself with such opinion as to expenses, as arises from a general view of the subject, and in this way I cannot think that the company can possibly, in the first instance, save £500 by erecting a small engine upon pit No. 10, rather than the large one recommended, to set against which difference, they will first have the materials of the present engine. 2dly. They will save considerably in engine keepers, for the present engine will require the same number as at present, with an additional number for the new engine, whereas, an engine upon my plan of seventy-two inches cylinder, will consume no more coals than the present engine requires per hour, when there is standage for the water, it will be worked by single shifts. 3d. The whole of the coals consumed by a lesser engine will, for the same reason, be saved. 4th. Which is most material, as the present business will be done under fifteen hours per day, there will be more allowance for additional water, and consequently more certainty in carrying the works regularly on.

I have only now to add, that a sett of seventeen-inch pumps, in three lifts, may stand in a pit of nine feet diameter, and after brattishing them off entirely, leave five feet of the pit's diameter clear, for drawing coals.

J. SMEATON.

Austhorpe, 9th October, 1779.

YORK WATER WORKS ENGINE.

DIRECTIONS for working the engine at the York Water-works.

Management of the flock.

OPEN the fire door when the steam is at the strongest, and with proper tongs of the shovel, spread thinly over the thin places, missing the black ones of the former feed, and keep doing this constantly, repairing the thin places, and keeping as good a body of fire as you can, which will be done by opening the fire door, and repairing more often than if you were working with coals; when the cistern is full, take the opportunity of cleaning your grate, which must never be suffered to grow foul.

Management of coals.

Break every coal that is bigger than a goose's egg, and the oftener you fire and the thinner the better.

Management of the cataract.

When the engine throws more water than the service takes, put on the cataract which is adjudged to eleven strokes per minute, if this does not keep up with the service, about six inches before the cistern is empty, throw off the cataract, and self work the engine till the cistern is full, then apply the cataract, and so on.

N. B. When the cataract is at work, ease the fire proportionally, and also take care to lessen the boiler's feed, less water being consumed in steam.

Management of the air cock.

After the engine is got to work out of hand, open the cock till it begins to flint a little water at each stroke, if it comes over hard, give it more air; in short, give it all it will take without spoiling the coming in of the engine.

J. S.

To

YORK

To the Gentlemen Proprietors of the York Water-Works.

GENTLEMEN,

FROM the experiments I tried, on Wednesday the 24th instant, compared with an experiment made before the proprietors, the 25th Nov. 1779, the following turn out to be facts, by deduction.

1779, Nov. 25.	The engine raised 244	hhds. per hour	$160\frac{1}{2}$	per mett of coals
1785, Aug. 24.	Per cataract	328		$240\frac{1}{2}$ of fleck
		328		$298\frac{1}{2}$ of coals
	Self-worked	$442\frac{1}{2}$		$357\frac{1}{2}$

DEDUCTIONS.

1st. From the above it appears, that the improvement of the engine, from 1779 to the present time, is in proportion of $160\frac{1}{2}$ to $357\frac{1}{2}$.

2dly. That the engine, when self-worked, makes a better produce than when worked by the cataract in the proportion of $357\frac{1}{2}$ to $298\frac{1}{2}$.

3dly. It appears from the account of fleck used from the 21st Feb. to the 23d Aug. that there were consumed seventy-three waggons, that is, 2044 metts of fleck, and the number of working days in the above time being 158, that will amount to near thirteen metts per day.

If the engine is supposed to work at an average seven hours per day, and an hour be reckoned for lighting the fire, this will be eight hours coals, and allowing $1\frac{1}{2}$ mett of fleck an hour, the consumption of fleck will be per day twelve metts.

4thly. According to the price of fleck, when deposited in the yard at 11s. 8d. per waggon, a day's work in fleck will amount to 4s. $6\frac{1}{2}$ d.

But, according to the price of coals, when deposited in the yard at 14s. 2d. the day's work of coals will amount to only 4s. $5\frac{1}{2}$ d. and if we could, in all cases, take off the water as fast as the engine can draw it, when self-worked, a day's work will be done with coals for 3s. $8\frac{1}{2}$ d.

5thly.

5thly. In 1779 they worked about $8\frac{1}{2}$ hours, and were an hour and a half raising the steam, and as they raised 244 hogheads per hour, in $8\frac{1}{2}$ hours they raised 2074 hogheads per day's service.

In 1785 we work seven hours, and raise the steam in three-quarters of an hour, but as we now raise 328 hogheads at common rate of working with cataract, in seven hours we raise 2296 hogheads per day's service.

J. SMEATON.

York, 29th Aug. 1785.

P. S. The cataract makes more of the coals than when self-worked, and the overplus thrown over into the Ouse, in the proportion of twenty-seven to thirty, or of nine to ten.

Date.	No.	Strokes.	Length of stroke.	Time.	Weight of coals.	Time of consumption.	Reduced strokes per minute.	Metts used per hour.	Hhds. raised in an hour.	Hhds. raised per mett.	
1779. Nov. 25.	1	12	5 3	1 0	24 0	1 19	$10\frac{5}{10}$	$1\frac{52}{100}$	244	$160\frac{6}{10}$	coals, self-worked
1785. Aug. 24.	2	10	6 0	1 3	11 $4\frac{1}{2}$	0 44	$9\frac{5}{10}$	$1\frac{28}{100}$	$328\frac{3}{10}$	$240\frac{7}{10}$	sleck, cataract
Do.	3	10	6 0	1 3	12 $5\frac{3}{4}$	0 $56\frac{1}{2}$	$9\frac{5}{10}$	$1\frac{10}{100}$	$328\frac{3}{10}$	$298\frac{7}{10}$	coals, cataract
Do.	4	13	6 0	1 2	11 6	0 $46\frac{1}{4}$	$12\frac{6}{10}$	$1\frac{24}{100}$	$442\frac{5}{10}$	$357\frac{9}{10}$	coals, self-worked

The above corrections were made in consequence of an error found out in the calculation, and were corrected at York accordingly, the 24th Sept. 1784.

If we compare the produce of the cataract with the produce self-worked, according to coals, say $442.5 : 328.3 :: 1.24$ to 9.22 , but per No. 3. the quantity used was 1.1, therefore too much in proportion, but $1.24 \times 9.22 = 1.4428$, whose root = 1.07, so that the saving by the cataract is nearly but rather short of a mean proportional between the reduction of coals, according to the quantity raised and self-working, if wasting the overplus.

* N. B. An experiment was tried the 24th September, 1785, of the difference between working by the cataract and self-working and stopping; the trial of self-working and stopping

stopping lasted three hours, in which there were three stoppages, which together made $47\frac{1}{2}$ minutes, that is at the average sixteen minutes; the time going was therefore 142 minutes, or $47\frac{1}{2}$ minutes each, say forty-eight, the time of going was therefore to the time of stopping as three to one, that is, they stopped one-quarter of the whole time. In this proportion, and the time so small of stoppage, the produce of self-working was better than that of the cataract in the proportion of twelve to thirteen; or one-twelfth part of the cataract's produce; but could the stoppages have been longer, the advantage would have been greater, as the damped fires grow foul, and extra coal is consumed by raising the fire.

A thirty-two inch cylinder will, at six fathoms, draw a pump of twenty inches bucket, and deliver 1150 hogheads per hour.

The same cylinder will, at twenty-seven fathoms, work a pump of ten inches bucket, and draw 288 hogheads per hour.

A cylinder thirty-two inches diameter should be eight feet long.

The diameter of the steam pipe 4 inches.

The boiler eleven feet diameter in the bulge, and nine at the bottom, which is to the nine inches.

M. B. H. called at a twenty-inch pump for draining the upper main coal waste, four pumps of ten inches are made use of, they will do the same thing; and all the pump pieces can be afterwards applied in turning the pump to go down to the low main coal, the clock pieces and working parts excepted.

J. SNEYTON.
Lumley Castle, 15th May, 1777.

P. S. Having viewed the ground where a wagon bridge is intended to be erected, I would advise to build cross walls at the distance of about twenty feet from each other, up to a certain level, and then to lay a couple of firs or Menai whole balks of twelve inches across upon the walls, and upon the balks to lay joists, and platform with way-gates in the usual manner as upon girders. If the walls may be each about twelve feet long, three feet thick at base, and diminished to two feet at top.

J. SNEYTON.
Lumley Castle, 15th May, 1777.

Vol. II. Y y LUMLEY

LUMLEY COLLIERY ENGINE.

DIMENSIONS proper for a Fire Engine for raising water at the New Winning of great and little Lumley Colliery, belonging to the Right Honorable the Earl of Scarborough, to answer effectually the quantity required by Mr. Edward Smith, in his memorandum of the 13th May, 1777.

A thirty-two inch cylinder will, at six fathom three feet, work a pump of twenty inches bucket, and deliver 1150 hogheads per hour.

The same cylinder will, at twenty-seven fathoms, work a pump of ten inches bucket, and draw 288 hogheads per hour.

A cylinder thirty-two inches diameter should be eight feet long.

The diameter of the steam-pipe $5\frac{1}{2}$ inches.

The boiler eleven feet diameter in the bilge, and nine at the bottom, which is to rise nine inches.

N. B. If instead of a twenty-inch pump for draining the upper main coal waste, four pumps of ten inches are made use of, they will do the same thing; and all the pump pieces can be afterwards applied in forming the pump to go down to the low main coal, the clack pieces and working barrels excepted.

J. SMEATON.

Lumley Castle, 15th May, 1777.

P. S. Having viewed the ground where a waggon bridge is intended to be erected, I would advise to build cross-walls, at the distance of about twenty feet from each other, up to a certain level, and then to lay a couple of Riga or Memel whole barks of twelve inches across upon the walls, and upon the barks to lay joists, and platform with wagon rails in the usual manner as upon geers. The walls may be each about twelve feet long, three feet thickness at base, and diminished to two feet at top.

J. SMEATON.

CHASE

CHASE WATER ENGINE.

CALCULATION of the effects to be expected from Chase Water Engine, and comparison with the former two engines upon the same mine.

See plates 6, 7, 8.

THIS engine is expected to go, with its full load of fifty-one fathom of main pumps, full nine strokes per minute, and being gauged, as per design, to $9\frac{1}{2}$ feet strokes, its common working stroke will be full nine feet.

The working barrels being full $16\frac{3}{4}$ inches; this, from the above data, will turn out per hour 880 hogsheds of water, wine measure, and I expect it to work at this rate with thirteen bushels of coals, London measure, per hour, supposing that all the steam necessary for working thereof be raised by boilers of a similar construction to what is proposed in the design to be placed under the cylinder; but as under this boiler alone, not above six bushels of coals per hour can be consumed with advantage, what is equivalent to the rest must be supplied from the proposed smelting furnaces; it is possible, however, by means of the Cornish cataract, to work it at the rate of four or $4\frac{1}{2}$ strokes per minute, with its full load, and, possibly, this boiler may furnish steam to work the upper column of pumps at its full rate of nine strokes per minute, till the second or middle column be prepared and fixed, without any help from the out-boilers.

Respecting the former engines upon this mine, it has been stated to me that

The larger cylinder of 66 inches drew an $18\frac{1}{2}$ inch bucket 24 fathoms.

And that the lesser of 64 ditto $17\frac{1}{2}$ ditto 26 ditto.

Total lift 50 fathoms.

That eight strokes per minute, of six feet each, kept the water down in summer, and ten in winter.

That engines of this size generally consume six London chaldrons per day, or 216 bushels, and that the two engines above mentioned consumed eleven chaldrons in twenty-four hours.

Now,

Now, as these two engines drew from one to the other, and took in no additional water by the way, the effect in reality will depend upon the lesser bore, and it will be found, by a calculation similar to the former, that a $17\frac{1}{2}$ inch bore, working a six-foot stroke and ten strokes per minute, will deliver 710 hogsheads, (wine-measure), per hour, which is less by 170 hogsheads than the calculated product of the new proposed engine, and is near upon one-quarter of the compound effect of the two former engines less than now proposed, so that what was done in twenty-four hours by the two former engines, will now be done in about nineteen hours twenty-two minutes; and even if the effect was to be computed upon the larger barrel, without paying any regard to the less, (which ought not to be admitted), its effect will be only 798 hogsheads, which is less by eighty-two hogsheads per hour than the proposed new engine, being near upon one-ninth of the former product less than the present, which would reduce the time from twenty-four hours to twenty-one hours forty-eight minutes.

The coals consumed before being eleven chaldrons in twenty-four hours, this will be at the rate of $16\frac{1}{2}$ bushels per hour; but as what was done in twenty-four hours will now be done in nineteen hours twenty-two minutes, the consumption per day will be only 252 bushels, equal to seven chaldrons, so that the natural motion of the engine being reduced by the cataract to do the same work, that is, to make delivery of the same quantity of water per hour, viz. 710 hogsheads regularly through the twenty-four hours, the coals ought to be reduced in the same proportion; that is dividing 252 bushels by twenty-four hours, and then the hour's consumption will be reduced to $10\frac{1}{2}$ bushels, at the average of twenty-four hours.

Still, however, this is supposing the new engine always to be raising as much water throughout the year, as has been found necessary in winter, but the former consumption of coals being regulated upon the mean of summer and winter, and the winter's water being to the summer's as ten to eight, as found by former experience, the mean will be nine, and the work of the new engine being less in the same proportion, that is as ten to nine, the coals will be again reduced from 252 bushels per twenty-four hours to 227, equal to six chaldrons eleven bushels, that is $9\frac{1}{2}$ bushels per hour upon the average of the year.

The performance therefore of the new engine, in point of effect, will be greater than the two former actually were in the proportion of four to five nearly, but the effect produced by the same quantity of coals will be as $16\frac{1}{2}$ to $9\frac{1}{2}$, that is, nearly as seven to four.

The

The above computation of the quantity of coals for the new engine, is on supposition of coals of the best quality of Newcastle; and, having procured a sample of coals from Wales, from William's colliery, which, as I have been informed, are the best engine coals used in Cornwall, I have found them very little inferior to the best Newcastle. Whether the coals used at Chase Water, for the two engines, were of inferior quality, I cannot say, but have no reason to suppose it, as the wrong general proportions stated, together with the errors commonly committed in the construction of these machines, are sufficient to account to me for all the difference.

It will, therefore, upon the whole, appear, that after the mine has been once cleared of water, supposing the quantity to be lifted, to be the same as before, that whatever expense of coals is saved upon $9\frac{1}{2}$ bushels per hour, upon the average of the year, will be in virtue of the new applications of the heat of the smelting furnaces.

J. SMEATON.

Austhorpe, 14th Feb. 1775.

P. S. On perusing my former dispatches, I find some small differences in the computations, but those have been chiefly occasioned by the different states of the former machinery and perpendicular height to be lifted.

J. S.

N. B. This engine, though not the largest that has been built, will be of considerably greater power than any I have seen, and when worked at its full extent, will work with a power of 150 horses acting together, to keep which power throughout the twenty-four hours would require at least 450 horses to be maintained. I have seen an engine of seventy-five inches cylinder, but that which worked with the greatest effect was seventy-two, and its effect equal to that of 108 horses continually acting, or of 324 horses to be maintained, which is less than the above in the proportion of seven to five nearly.

ADDITIONAL.

ADDITIONAL REMARKS upon particular parts of the engine for Chase Water.

PLATE VI. contains an upright section of the whole engine, which in general explains itself to those who are acquainted with the general principles of the fire-engine; what follows is descriptive of those parts, which require particular management in the execution.

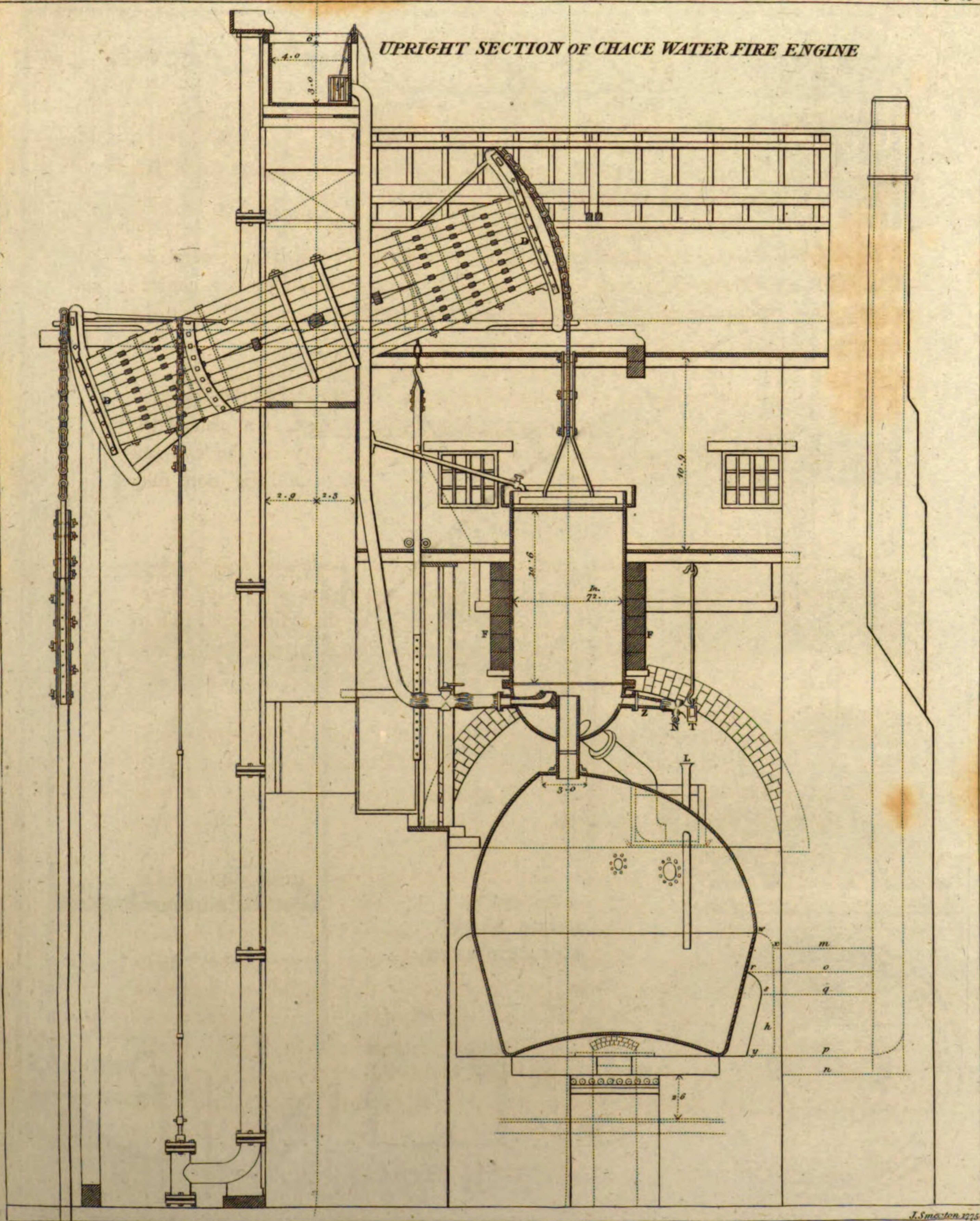
Plate VII. fig 1, is a plan of the lower side or working surface of the regulator plate, which is situated in the top or crown of the boiler. Fig. 2, is a plan of the metallic plate, which works against it; and fig. 3, a section shewing the two put together. Figs. 4, 5, 6, 7, and 8, refer to the working geer, as will be more fully explained.

Plate VIII, fig. 1 and 2, shew the method of supplying the boilers of a fire-engine with fresh water. Fig. 3, is an elevation of the piston and chains for Chase Water fire-engine. Fig. 4, a plan of the piston. Fig. 5, a section of the cylinder and piston. Figs. 6 and 7, a plan and section of the injection cap; and figs. 8, 9, and 10, explain the manner of uniting the pump rods to the chains.

Fig. 4, of pl. VIII. shews a plan of the under surface of the piston's bottom, which, as there shewn, must be a planking of wood, and by the bolts and rings A A and B B, must be fastened to and under the cast-iron piston plate C D, fig. 3, in the manner shewn by the section fig. 5.

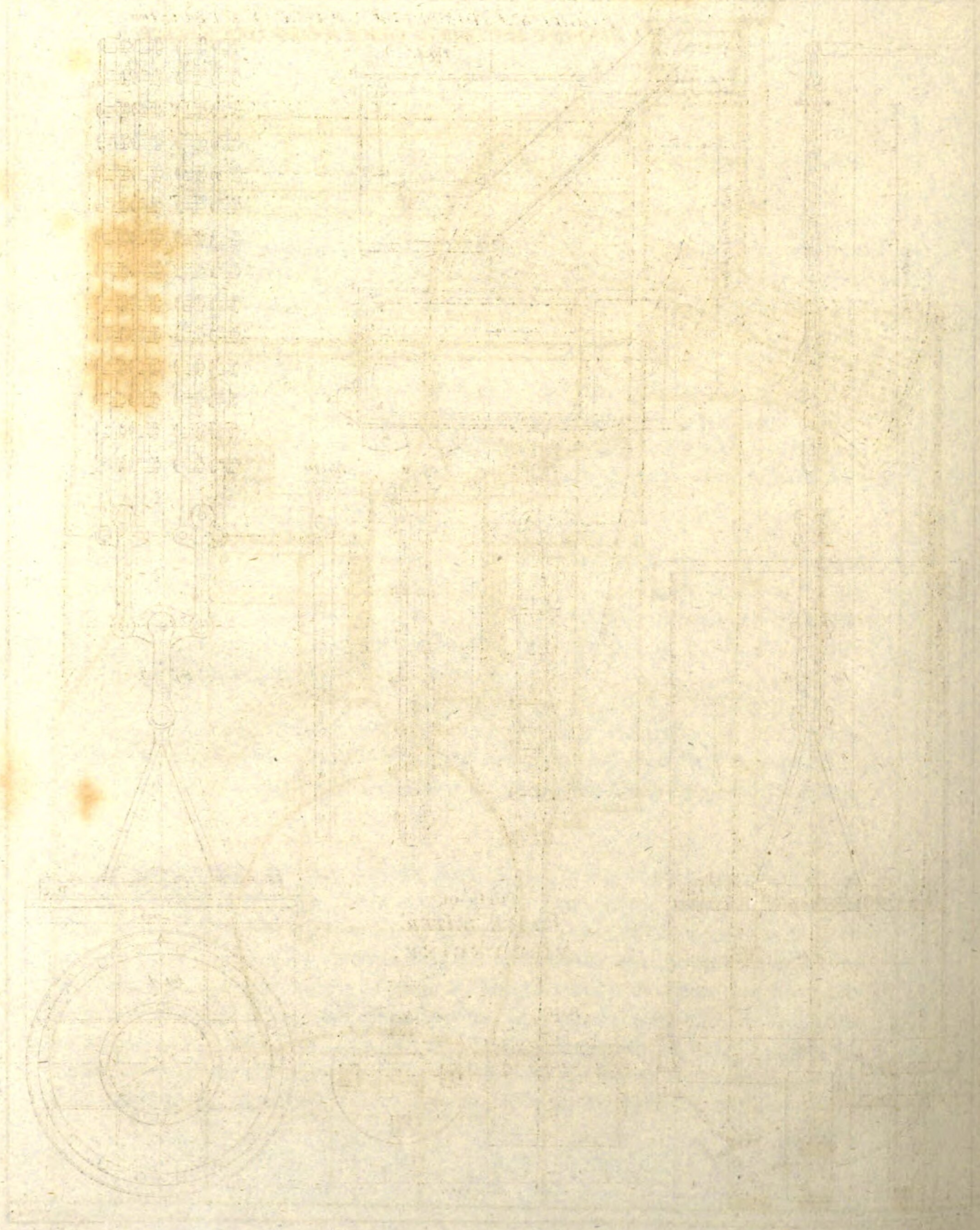
This planking to be of elm or beach, about $2\frac{1}{4}$ thick when worked, the edges of the two planks forming the cross, to be grooved with a plow plane, about three quarters of an inch wide, and as much in depth, and the corner pieces being tongued, so as to fit thereto, this, with a few rivets to hold the cross planks together where they are to be halved into each other at their intersection, being hooped with a good iron hoop half an inch thick and $2\frac{1}{4}$ broad, will bring the whole tight together; the ring out and out to be a quarter an inch less than the cylinder. The flat iron rings shewn in fig. 4, upon the under surface of the piston, are to be let in flush with the surface of the wood, and the bolt heads to be chamfered or counter-sunk, so as to be flush with the ring. The
planking

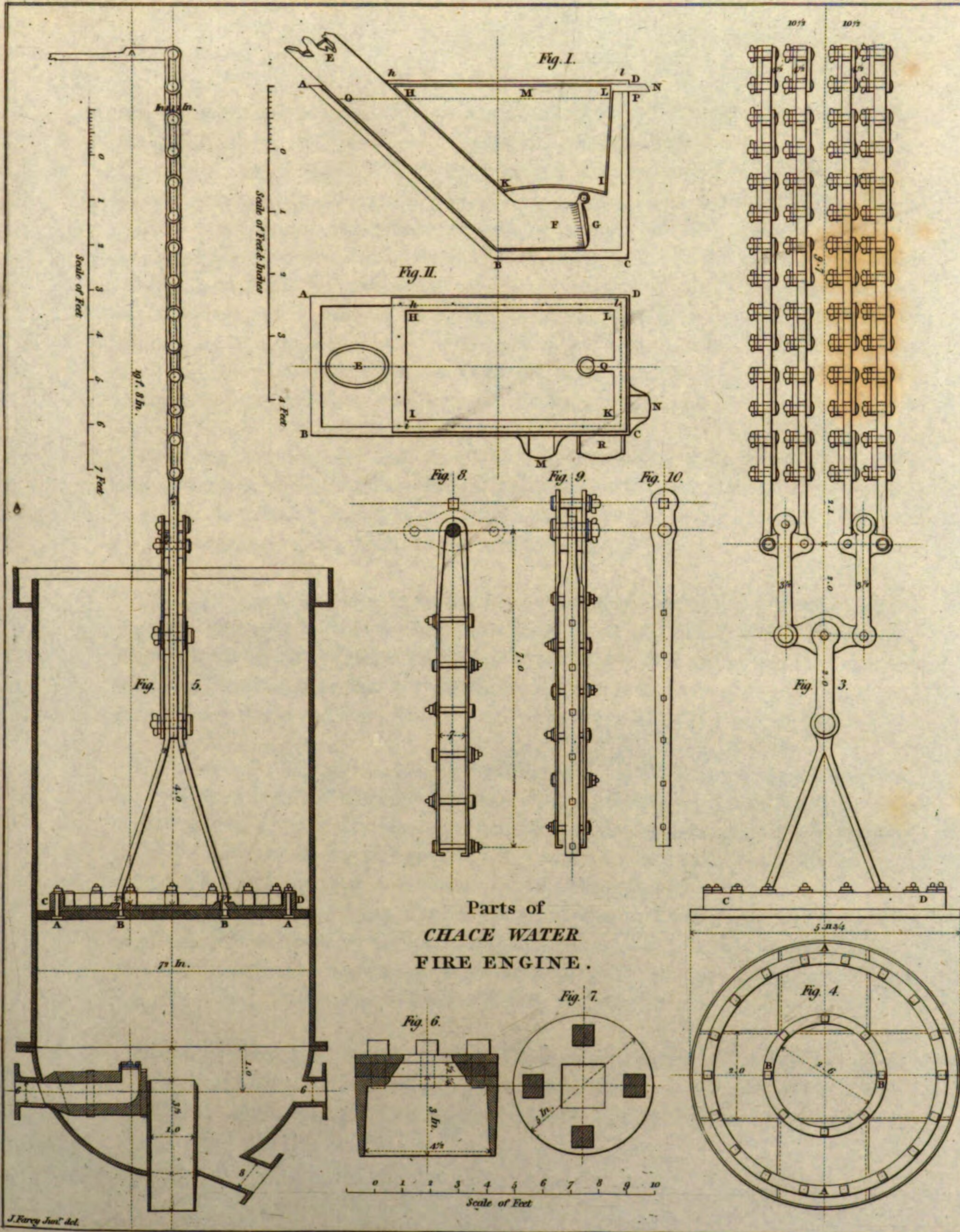
UPRIGHT SECTION OF CHACE WATER FIRE ENGINE



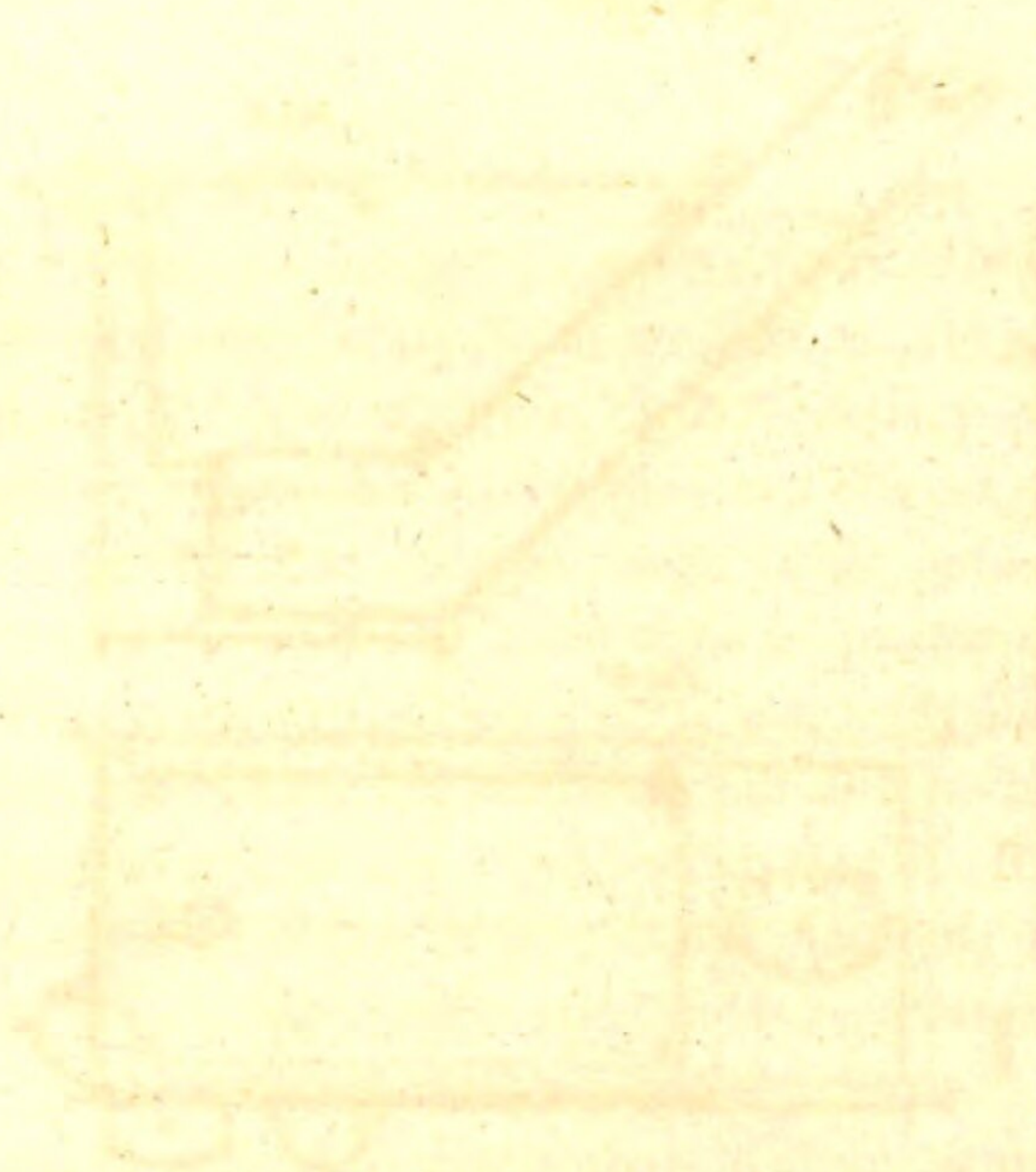
J. Farcy Jun. del.

J. Smooton 1775.
W. Lowry sculp.





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planking to be screwed on with a double thickness of flannel and tar betwixt that and the iron piston plate, and in case of irregularities, the hollows to be filled up with additional thicknesses of flannel, &c. so as to exclude the air between the plate and the wood, the bolts to be also carefully secured so as to make a water tight joint from above. The planking being thus prepared, a sheathing of deal boards, shot clear of sap, and three quarters of an inch thick, must be nailed on to the planking, with tar and hair, or a single thickness of flannel, so as to exclude the air between the planking and sheathing, and at last the sheathing to be dressed off, so as to be perfectly flat and smooth. N. B. If any parts of the piston flanks happen to be prominent, they may be let into the planking, and the air extruded from the cavity by some proper matter applied, as tar and hair, white lead and oil, &c.

The space that may, and, indeed, ought to be left, in setting the boiler and cylinder between the top of the regulator's steam pipe, and the bottom of the cylinder's steam pipe, may be fitted up with a ring of iron or lead, so as to make a smooth inside, and support the wrapping which was bound round it to make the joint.

The regulator is supposed to be fixed upon a copper plate adapted thereto, and to the top of the boiler; this very little to exceed one-eighth of an inch in thickness; the part covering the opening of three feet at top of the boiler to be set (not concave or convex), but as little flat as possible, by which means it will spring up and down, and give way to the working of the engine, without straining the joints.

The upright feeding pipe L, in the general upright, pl. VI. is here designed to answer, not only the purpose of a lower gage cock, but of a safety pipe, which will be done by boring two or three gimblet holes through it at the depth proper for a lower gage cock, and three inches lower than these holes, to bore a hole of half an inch diameter, and three inches below that to terminate the pipe altogether: by this means, when the water is got too low, the small holes will give notice by producing a rackling noise; when the steam blows by the half inch hole, the noise will produce a greater alarm, and when so low as at intervals to get to the bottom of the pipe, the water and steam will issue in such a manner as to awake the dullest apprehensions.

In the injection cap, figs. 6 and 7, pl. VIII., is shewn a square hole of $1\frac{1}{2}$ inch square, which is supposed to be sufficient when the engine has got its full lift; but it is hardly necessary to say, that when first set a-going, it should be much less, by being plugged up,
or

or originally pierced to half an inch, and enlarged, as the weight of the column makes it necessary. To avoid the trouble of drawing the piston, to perform this enlargement gradually, often occasions much mischief at starting; it is, therefore, of consequence to have the tackle for drawing the piston, such as to do this business handily and readily; for this purpose, let an iron cross of a competent strength be provided, the whole length of one bar to be about two feet, and a shorter welded across it of about one foot, or fifteen inches; the two longer ends to be terminated with an eye or loop; lastly, provide a rope of competent strength and length, with a hook at each end, suppose in the whole about two yards long, then the shorter two arms of the cross being introduced between the branches that are united at top, the larger arms being in a parallel situation to the cylinder beams, and the two hooks of the rope applied to the two eyes of the cross, hook the lower tackle block to the middle of the rope, and applying the purchase, the chains will be eased of the weight of the piston, without altering their situation, by which means the great bolt will be easily drawn out, the piston raised in its proper situation, and the business being done within, may be restored to its place again, with little loss of time or difficulty.

As the piston has frequent occasion of being rested upon the cap at the top of the cylinder, and as the weight is apt to bilge it when made of lead, it would be proper to order it of cast iron; and if the piston head water is supplied by introducing a pipe through the side of the cap, making the cock a stop cock, then the top of the cap will be clear to rest the piston upon without disturbing that pipe and cock, and some precaution in these respects is the more necessary, on account of the wooden bottom.

Respecting the great working beam, sufficiently shewn at D D, pl. VI. The great plate for the gudgeon being five inches in thickness, the two pieces on each side the middle are made of whole barks, of twelve inches square when dressed, these are notched in three quarters of an inch on each side to keep the gudgeon plate steady; they are then scarfed and sprung together as per design, and moulded off upon the outside towards the extremity by a fair curve, according to the design.

It is best to spring these four pieces together before the rest, and leaving them a little longer than the others, confine them together by hoops at the ends, and the curve thereon being made fair, the plank pieces are to be brought on upon them by strong notched pieces of wood, which the carpenters call clamms, several on each side, between
the

the places where the bolts are to be; these, by wedges, will bring all together, then the bolts and plates are to be fitted, and all brought tight; lastly, the plates for the drift keys are to be mortised out, or, to save trouble in boring and mortising, a little attention to measures will enable the ingenious carpenter to nick the pieces with a saw, and split out the cores, before they are brought together, and being made a little too short at first, either in this case, or in that of actually mortising, they are to be very carefully dressed with a heading chisel; after this, the keys are to be adapted with a plane, one by one, easing the parts that bear; the keys are to be made of heart of oak, perfectly dry and hard; those keys are to have no drift sideways, that is, to be quite parallel with respect to their thickness, but to take their drift altogether endways of the mortises, being six inches at one side, and five the other. And N. B. If any key fits well, but drives too far, or, by tightening occasionally after the engine is set to work, gets driven too far, it is better to put it in with a strip of paste-board, or other matter of an equal thickness, than make a new one, as hereby the parts are sure to fit. It is necessary to say, that the dressing the heads of the mortises as near as may be to a straight line is the principal nicety of workmanship that is required.

Respecting the cylinder beams shewn at F F, pl. 6, upon which the cylinder rests, and which are kept down by being entered into the side walls of the house, it is to be observed, that the key's being fixed in the same manner and form, and for the same use as the great beam; the same care must be observed as to the matter and fitting thereof.

As the bolts of the spear plates are the most liable to fail, in figs. 8, 9, and 10, pl. 8. is shewn a method of making them of a very increased strength, without weakening the wood more than usual, by making them square $1\frac{1}{2}$ inch by one inch, the breadth-ways upward, and by bringing the whole substance through the plate upon the nut side as well as the head side; but if this increase of projection is objected to, it may be sufficiently reduced by using drift keys instead of screws and nuts, which will at the same time render the work more simple.

The same method as is shewn in cramping the ends of the plates for the top of the main spear will be proper also for the top of the spear plates in ordinary, the cramp or cock part being not more than about five-eighths of an inch. The spear is supposed to be single till you go down near the upper pump head, then it is proposed to be divided into three flatways by the usual method: but I have to remark, that the upper-

most pump should answer the middle spear, by which means, the weight of dead spear on each side the middle will be the most equal possible, and on that account less liable to swag in working. And N. B. As the pumps being in different heights, will not interfere, the outsides may be brought nearer the middle, if found more convenient.

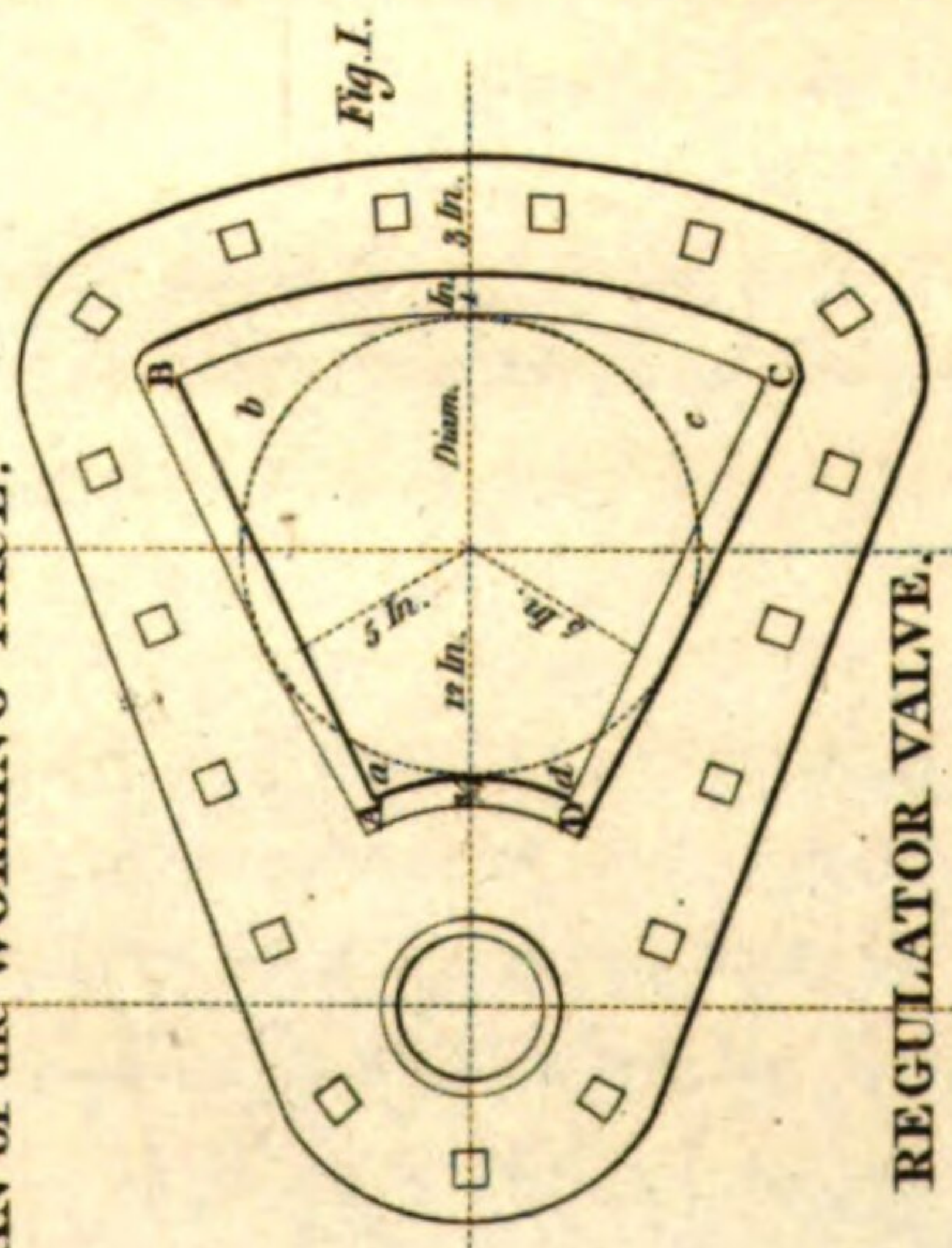
The upper end of the spear is shewn, fig. 8. pl. 8. to be seven inches square, and so to continue to the division into three; but I apprehend for the greater security in jointing, it may be more eligible to make it of eight by six, or rather ten by five, and at half way between the top and bottom to cut away half its breadth, reducing its breadth by a shoulder to five inches square. Suppose the length of spear wood fifty feet, then the shoulder will be at twenty-five feet from the top; here bring on another piece of five inches square and fifty feet long, which will exceed the first piece by half its length; secure the pump joint with three spear plates one on each side, and one opposite the side where the wood is whole, cross bolting all together in the method already shewn; and to the shoulder formed between the two pieces last joined apply a third, exceeding the former by half its length, securing the butt joint as before, and so going on till you have got your length. By this means, one half of the wood will every where be whole, and the other half secured by spear plates in the best way; and still the better to keep the whole together, and from drawing, in case of any failure in either half, between two of the last bolts next the ends of the spear plates (that is, between the two five inch pieces), apply a key of dry oak, of one inch thick, and five inches high, as is shewn for the cylinder beams, and working beam; and also two more at equal distances between each sett of spear plates, putting a clink bolt through both pieces, one on each side the key. The other spears after the division I suppose to be made and secured in the usual way.

As the wear of the leather of the bucket, and consequently much trouble, depends upon a proper manner of sizing and making the buckets' hoops, I shall here add some notes thereon.

The bucket hoops on the outside should be a cylinder, that is, the same diameter above and below their tapering or conical inside, must therefore be formed by the different thickness of the metal, their external diameter should not be more than one quarter of an inch less than their respective barrels, that is, they should be as big as possible, so as to allow for the unequal thickness of the leather without jamming the hoop,

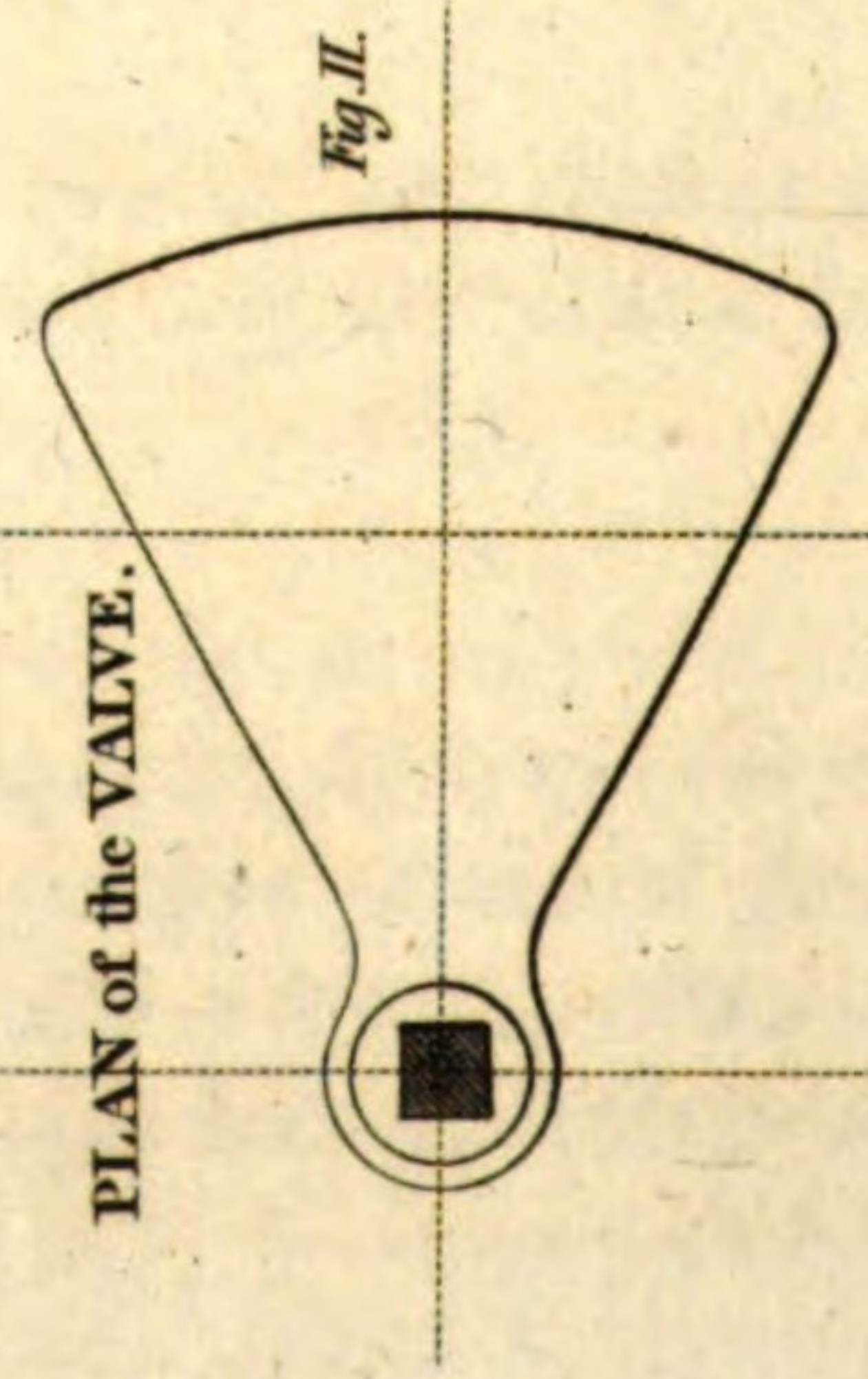
WORKING GEER for CHACE
WATER FIRE ENGINE.

PLAN of the WORKING FACE.

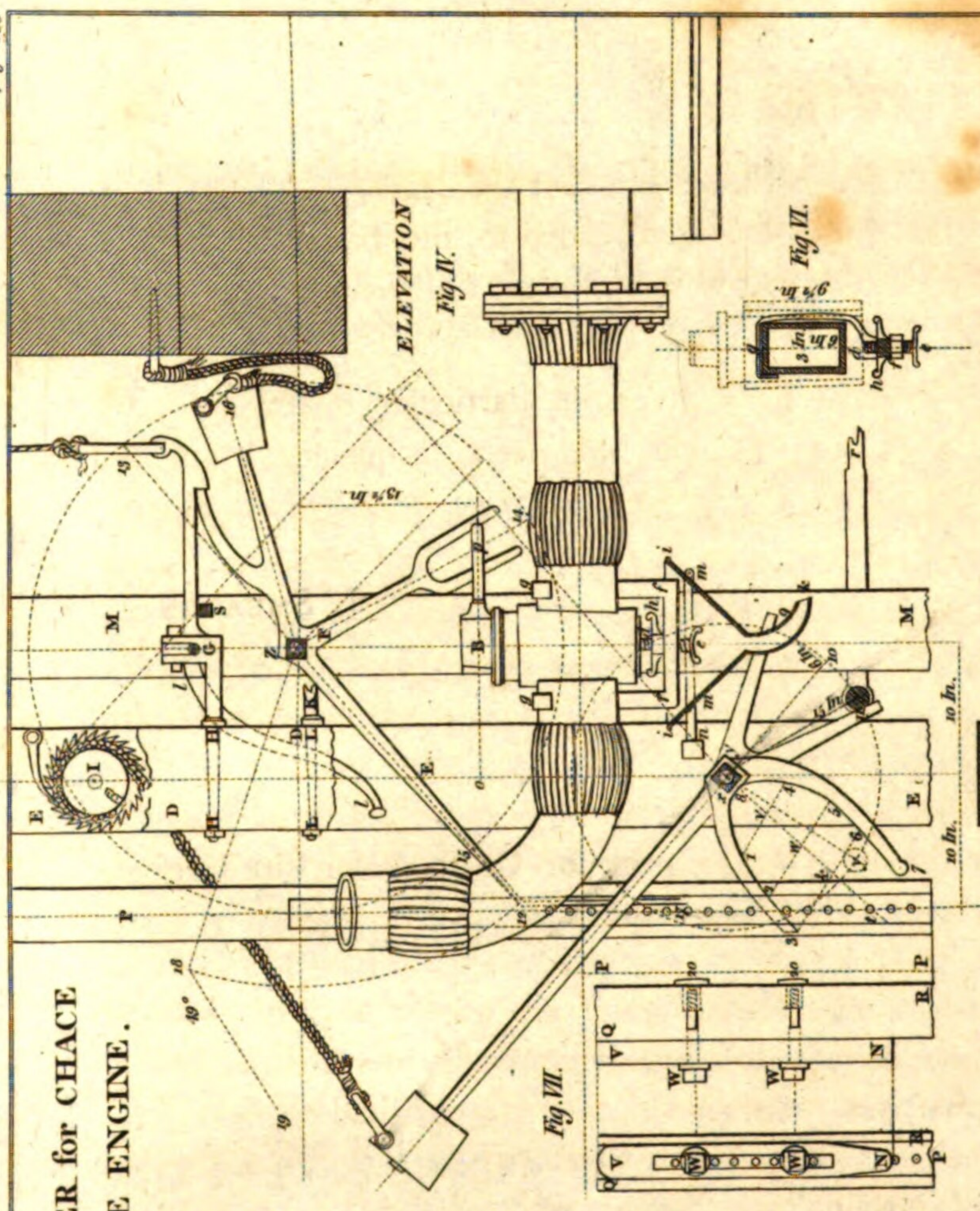
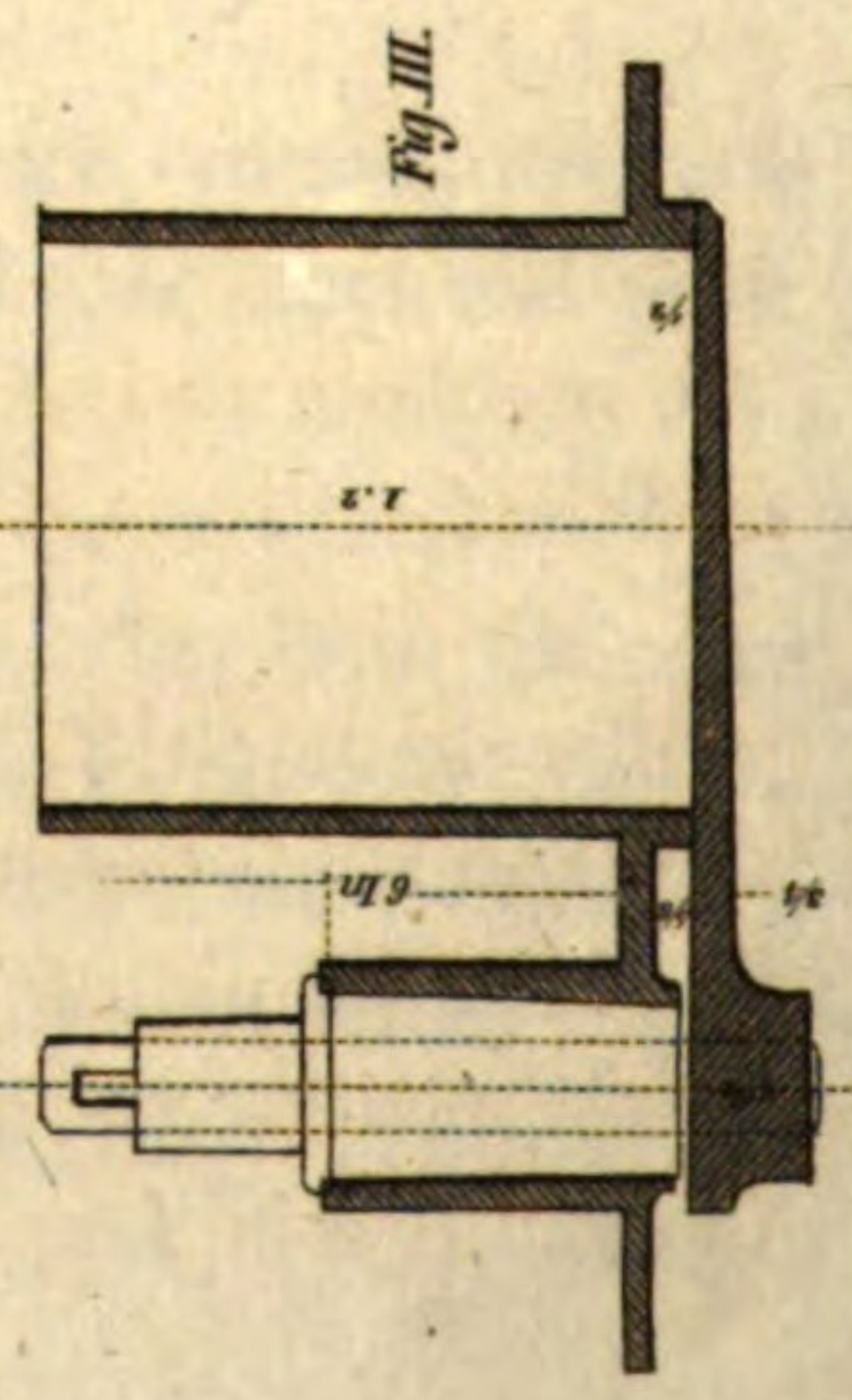


REGULATOR VALVE.

PLAN of the VALVE.



SECTION thro' the MIDDLE.



Scale of Feet
0 6 12

Scale of Feet & Inches
0 1 2 3

Fig. VIII.

Fig. V.

Fig. VI.

Fig. VII.

Fig. IX.

Fig. X.

Fig. XI.

Fig. XII.

Fig. XIII.

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hoop, the hoop to be made as broad as can be allowed, but the leather need not stand above an inch above the hoop; this being carefully attended to, the barrels will be as little as possible subject to chamber, either by the hoop or the leather.

And N. B. Once for all, that where I have given no particular directions, as I suppose myself addressing my designs to ingenious engineers, acquainted with the usual practice, I suppose the thing to be done in the usual way, or subjected to convenience and their discretion.

J. SMEATON.

Austhorpe, 13th February, 1775.

EXPLANATION of the design for the working geer for Chase Water Fire Engine,
Figs. 4, 5, 6, 7, and 8, of pl. VII.

IT is unnecessary to enter into a minute description of the operation of those parts which are made as common, and are obvious to all practitioners in this kind of work; it is sufficient to explain those that are more uncommon and particular; and it is sufficient to say in general, that the parts being exactly measured off from the scale, and enlarged according to the design (paying due regard to what follows the position of the great parts first fixed), all the pieces will come together, and do their respective offices without material alteration, and that though many other and different proportions will answer the end, yet these will be found to do their respective offices completely, and work kindly.

The cylinder, the boiler, with the regulator and the beam, with the plug frame, being fixed as per general design, pl. VI. and directions; the angle must be examined that the regulator and injection cock must turn in, in order that they may completely open and shut.

The geometrical figure in the plan, fig. 8. pl. VII. represents the different positions of the regulator's spanner, in which it is open and shut, wherein A represents the socket, in which the pin of the regulator turns, which (to bring the drawing into a less compass) is supposed to be brought forward from its true position towards the working geer; the line A a is supposed to be square to the position of the great beam, and parallel to the

the cylinder beams, the line $A b$ is supposed the spanner's position when the regulator is shut, and $A c$ that of its being open; the arc $b a c$ will therefore be the arc of a circle comprehending its shut and open position, which is here supposed fifty degrees, whereof the angle $b A a$ is twenty, and $a A c$ equal to thirty degrees. The radius of the circle, or length of the spanner $A b$, reckoned from the centre of the socket to the point in which the sliding rod joins, is proposed to be fifteen inches, and the stirrup that suspends the other end of the sliding rod $x y$, fig. 4, is to be of twelve inches length; the middle line, therefore, of the regulator passing through the centre of the socket, and the centre of the steam pipe, will be parallel to the line $A b$, and not to the cylinder beams, and the line $A a$. N. B. The angle $b A a$ is made less than the angle $a A c$, because the sliding valve is hardest to move in its shut position; in all others, it being but little confined, except by its own friction.

Fig. 6, is a section of the square water-way of the injection cock, the dotted lines shew the relative size of the cock pin and socket, the mean diameter of the cock pin being five inches will allow to be pierced three inches wide, and $5\frac{1}{2}$ inches high, and a pin of this size being of a considerable weight, to ease the friction it will be proper to support a part of the weight upon the point of a screw supported by a kind of springing frame, or double hook hanging upon the square branches of the cock on each side of the pin, which is represented in figs. 4 and 6, wherein $d e$ is the screw pin $f g$, $f g$, is the spring frame, and h is a counter nut to keep the screw from slacking by the circular motion of the pin; this frame hangs loose, without any confinement, but is kept to a place by the point of a screw, and as the hooks are made slight and thin, to allow them to spring, any part of the weight of the pin may be supported till it is found to open with the necessary freedom; it also prevents unnecessary wear, both of which are material to the performance of the engine.

All injection cocks should have their pins made to take out, in order to be frequently greased with hogs-lard, or other soft grease, with a valve at the top of the injection pipe, or some other equivalent contrivance to take off the water while this is doing; and as experience shews, that by the incessant motion of the engine, injection cocks will not remain long tight, a contrivance to the amount of what is shewn in fig. 4. will be necessary to catch the water, wherein $i i k$ is the section of a tunnel of strong tin, or thin copper, supported by an iron ring, whose section appears at $m m$, with a branch n , (see also fig. 5.) by which it is fastened to D , one of the pillars of the working geer; the water issuing at k may be received into a small wooden spout, and conveyed to the waste water.

An

An injection cock made in the proportions above specified, or almost any common cock, will completely open and shut in the angle shewn in the plan fig. 5, wherein B o is the position of the cock's spanner open, and B p that of it shut; and the angle o B p, the angle in which it turns, so as effectually to open and shut, being nearly eighty degrees.

The height of the regulator's spanner being given, as y y r in fig. 4, the height of the tumbler's centre x will be had, by setting up ten inches, as per design; and the height of the injection cock's spanner B being given, the height of the centre z of the piece marked and called the F, will be had by setting up B z, equal to $13\frac{1}{2}$ inches; the distance of the two points o p, in which the acting radius of the fork, z o, z p, meets the spanner, being equal to the distance of the same two points so marked in the plan, fig. 5. The distance B q of the plane of the F from the centre line of the injection cock, is $7\frac{1}{2}$ inches, but by bending the fork a little towards, or from the cock, it will cause the spanner of the cock to turn in such a greater or less angle as shall be sufficient.

In fig. 4, D D, shew a part of the fore pillar (marked in the plan fig. 5. D), the rest being supposed broken off, to shew the better what falls behind it; the rest of the upright piece E E E being the far pillar, marked in the plan fig. 5. E, the better to support the F, and keep it steady in its working; it is fixed upon an axis of a competent length, and its catch above is also fixed upon a like axis; the fore end of which is supported by an arm from the fore pillar D, marked G H H; the arm supporting the near end of the F axis, is perfectly similar, but here shewn broke off, as K L L, the more distinctly to shew the shape of the F; the far ends of both axes are supported upon a back pillar M M, as they could not go across to the far pillar E, on account of interfering with the tumbler, or y, so marked and called. The pin or stud at S, driven into the pillar M, is to support the catch from falling too far after the F is discharged, and the tail t t, attached to the axis of the catch, serves as a handle to strike off the injection in hand working.

In fig. 5, the catch, with its axis and arm lying directly above those of the F, is supposed removed, in order to shew those of the F, but the place of the catch tail is shewn at l l, it being not otherwise determined.

The only parts that require an exact form, are the F, and the two arms working in the plug frame, which may be moulded by being drawn upon a board or table as follows:

For

For the arms of the tumbler, first form a square equal to, and representing a section of its axis, draw a line, representing $x t$, right across the square, according to the measures set off the points $8 v w$ and t , and at these points cross the line $x t$, with the perpendiculars $i v 4$, $2 w 5$, 3 and 6 , $t 7$, setting off the points $1 2 3$, on one side, according to the distances $v 1 w 2$ and 3 , measured from the scale, and in like manner, the points $4 5 6 7$, from the distances $v 4$, $w 5$, and $6 t 7$, on the other; this done, draw a fair curve through the points $3 2 1 8$ on one side, and a fair curve through $7 6 5 4 8$, on the other; and lastly, fixing on a square piece of wood or iron, upon the square, representing the axis, the board is prepared; then the arms being ready formed in iron, and the squares made to fit the axis, apply the square hole in the arm upon the prominent square on the board, and having heated the iron as much as necessary, bend each arm till its working face answers to its curve respectively.

The legs of the y may be set to a proper opening, by drawing a circle as yy , $10 9$, of a radius, equal to the length of the stirrup, viz. twelve inches, and from a middle line $x 10$, setting off five inches each way, from ten towards nine, and from ten towards eleven, and applying the y in like manner, upon a central square, open the legs till the insides touch the two points eleven and nine respectively.

The figure of the F will be constructed by drawing a right line, representing $12 z 13$, and making the length $12 z$, equal to two feet two inches, then striking the arc of a circle $13 14 15$, draw the line $z 14$, so that the angle $15 z 14$ may be, as here, of seventy-five degrees, and this line $z 14$, will give the middle line of the fork; and setting off the arc $14 16$, equal to the arch $14 15$, the line $z 16$ will give a proper position for the middle line of the faller. The angle $z 12 17$, or which is the same, $z 18$ and 19 , is of 131 degrees, or forty-nine degrees, from the straight line; lastly, marking in the proper thicknesses, and branch to lay hold of the catch, this will be a mould for making the F .

The position and shapes of the other parts will be readily determined from the eye, or by measurement from the design; but it must be carefully observed, that wherever the measures marked upon the plan differ from those resulting from the scale, the figured measures are to be adhered to; and N. B. the same letters denote the same parts in all the figures.

Fig. 7, shews the manner in which a slider may be fixed upon the plug frame, instead of the pin marked in the plan at N , and in fig. 7, is shewn by the rounded end of

of the slider at N. This figure shews a part of the plug frame, with the slider annexed, in two positions, wherein the dotted line P P, representing the middle line of the plug frame; the position No. 1, shews the left hand half of it, as seen in front, the spectator's back being towards the pit; and No. 2, shews the plug frame as seen sideways, but on the opposite side to what is shewn in fig. 4. In both positions of fig. 7, Q R, shew a part of the plug frame; N V the slider; and W 20 W 20, shew the screws for retaining the slider in its place; by this means, the stroke may be adjusted, when the beam comes in, by smaller differences than what the distance of the holes would occasion, as is adjusted going out, by more or fewer saddle pieces of leather.

At the letter I. fig. 4, is represented a roller that reaches from the pillar D to the pillar E, furnished with a ratchet and catch, to adjust the check rope to a proper length. And N. B. a soft matted rope soaked in tar answers well for this purpose, having but little elasticity, and the same for the faller of the F.

A sliding rail for the regulator's spanner to rest upon is not here represented, as being a thing of course.

N. B. If the weight of the tumbler falling towards the cylinder, should not sufficiently shut the regulator, the long shank of the y may be bent over a little from a right line towards the cylinder, which will in effect counteract the weight of the arms, acting in a contrary direction.

J. SMEATON.

Austhorpe, 27th February, 1775.

CRONSTADT

CRONSTADT ENGINE.

DIRECTIONS to be observed in adjusting the Engine for Cronstadt to its work*.

1st. THE whole of the engine being put together and in place, but the buckets without leathers, and the piston without wad or ramming, lay 32 cwt. upon the piston, and try by levers or small tackle, whether the beam, with all its accompaniments, are in balance, that is, whether the resistance to motion be equal both ways; if it be, it is well, if not, put as many of the balancing weights on one or the other of the great beam as shall bring the whole to a balance, or indifference to motion either way, there fix the balancing weights and take away the 32 cwt. from the piston, and the engine when at work will be in proper trim. N. B. It is expected that with full steam the engine will go quicker out than in, and if so the balance must not be altered on that account.

2dly. Take the mean diameter of the valve of the puppet clack or safety valve in inches and decimal parts, and multiply it by itself, and the integral parts of the product will be the number of pounds, and the decimals the parts of a pound, that is to be the whole weight of the puppet clack with its load; thus, if the puppet clack is $5\frac{1}{2}$ inches, it will require its weight to be $30\frac{1}{4}$ lbs. including the weight of the moving part of the valve itself.

3dly. A small cock, such as are used for wine or spirit casks, must be fixed upon some convenient part of the upper side of the sloping sink or eduction pipe, not only to give air to fill the cylinder when the work is over, but to give a small quantity of air while it is working. On setting agoing this cock must be shut, and the snift cock open; when the engine is got steadily in motion, diminish the snift by closing its cock till there is not more appearance of steam in the whole of one stroke, than would amount to the apparent bulk of a hoghead; when this is done, gradually give vent by the air cock till the beam will but barely come down to the springs at the cylinder end when the steam is full, and when weak to strike short by about six inches.

* This engine being constructed in the same manner as that of Chase Water, it would be unnecessary to give the design, it will be sufficient to state the following dimensions, in which alone it differs from the former.

Diameter of the cylinder	.	.	.	5 feet 6 inches
Length of the stroke	.	.	.	8 6

4thly.

4thly. Choose a coal that affords a bright clear flame, such as the splint coal of Scotland. Small coal, approaching to dust, or round, in large pieces, are equally to be avoided; coal, from the size of a sparrow's to that of a hen's egg, answer best in proportion to their weight; feed the fire a little at a time and often, spreading the fuel equally over the grate; it is no matter how few red coals compose the fire.

Keep up the steam so as always to shew a little waste when strong, and as soon as ever the engine is found to fall off from its motion, repeat the feed.

N. B. This engine is expected to go at a mean rate of $9\frac{3}{4}$ strokes in a minute, of $8\frac{1}{2}$ feet each, with $7\frac{1}{2}$ chaldron of coals in twenty-four hours, London measure, of the best quality of Newcastle or of splint coals, which I account for working a fire-engine as equal thereto. This will produce 27,300 tons of water in twenty-four hours to the height of fifty-three feet, and is equal to the labour of 400 horses. But, if the engine goes $9\frac{1}{2}$ strokes in a minute, of eight feet each, this will more than satisfy my proposition to Sir Charles Knowles; that is, to raise 24,300 tons per day to the height of fifty-three feet, with $7\frac{1}{2}$ chaldron, London measure, of the best Newcastle coals, in twenty-four hours. This is an effect considerably greater than that of the largest engine yet built in Britain.

J. SMEATON.

Austhorpe, 1st March, 1775.

GATESHEAD PARK ENGINE.

DESCRIPTION of the method of supplying the boilers of a Fire Engine with soft water.

See plate, 8, figs. 1, 2. (page 350.)

IT has been the general practice, and found very advantageous, wherever the situation will admit of it, to supply the injection water of fire engines with the water of a burn or rivulet of soft water, or from a soft-water spring, in consequence whereof the boilers of such engines become in course supplied with soft water, which is the only water that can be depended upon not to fur the boilers, the very great advantage whereof is well known and experienced; but where the situation does not admit of a supply from a rivulet or soft-water spring, as is generally the case, the quantity necessary for the supply of the injection of a fire engine is so considerable, that still fewer situations admit of making an artificial reservoir or reservoirs of sufficient capacity to supply the injection water in the interval between rains and great showers; so that for want of any tolerable certainty in this matter, recourse is usually had to the raising of water from the main-pump heads of the mine, which, in general, is not only of a hard nature, but frequently so corrosive and adhesive to the boilers, as to do them more prejudice in three months, than as many years would do them if worked with soft water. It, therefore, appeared to me as one of the greatest improvements that could be made to the fire engine, to be enabled to supply the boilers with soft or rain water in all situations; that is, particularly in those situations where, as above mentioned, a supply of soft water has not as yet been attempted; and this idea led me, in the course of experiments. I went through some years since upon the fire-engine, particularly to investigate the quantity of water that was necessary for injection, in proportion to the quantity that was necessary to feed the boiler, and I had the satisfaction to find that the latter was in most cases less than one-twelfth part of the former. It also occurred to me, that since the boiler will not feed unless the hot-well water is let into it by the feeding cock, if the small quantity necessary for the feeding can be separately supplied from a reservoir of rain water, and the chill taken off, so the smaller quantity may be warmed in a degree by the great quantity of hot-water produced from the injection; then the engine may be worked by injection water of whatever quality, provided it be cold, and the boiler may be fed by such only as is of a good quality, without any communication except that of heat.

With

With this view I placed in the hot-well of my experimental engine, a pan made of tin, as large as could be placed therein, leaving a vacancy between the sides of the hot-well and the sides of the pan, for the injection water to ascend, and to pass off at the hot-well spout as usual. This pan was then continually supplied with cold water from a neighbouring well, in such quantity only as continually running off into the boiler kept up the feed therein; I did not find any sensible difference in its product of work in proportion to the coals used, than it did in its ordinary way of being fed upon the hot-well.

The following method, therefore, founded upon the above experiments, is what has since occurred, as being the best and easiest way of applying those principles, and which, on supposition of a reservoir large enough to hold water betwixt rain and rain, cannot fail of success.

Fig. 1. is supposed to be a section of the hot-well, wherein

A B C D—Shew the hot-well, supposed to be cut through the middle.

E F G—Part of the sink pipe, with the horse-foot valve.

H I K L—Shew a section of the copper pan made to fill as much of the vacant space of the hot-well as possible, it may touch the sink-pipe, and but just clear the joint of the horse-foot valve, the bottom being a little rounding, and about an inch higher at the point I than the point K, in order to induce a part of the injection water to ascend towards the part H, which, without that advantage, it would not be apt to do, the conveyance-spout being near the part L, but the three sides of the pan that apply themselves to the three sides of the hot-well, are to be about $1\frac{1}{2}$ inch distant therefrom at the top, and about two inches distant at the bottom of the pan; and, according to these directions, the absolute dimensions of the pan is to be taken from that of the hot-well.

Now, the feeding water being brought and let fall into the pan by a lead pipe from the feeding reservoir, it will be continually receiving heat from its immersion in the hot-well water, up to the dotted line O P, and must be continually passing off by two spouts, one marked M, the other N, from whence the water is to be conveyed to the feeding pipes of the two boilers.

Fig. 2. is supposed to be a plan of the hot-well and pan therein, wherein A B C D represent the top of the hot-well, E is a section of the sink pipe, and R the conveyance spout for the hot-well water.

H I K L—

HIKL—Shew the top of the pan, which, being flanced an inch, or all the four sides, is to be rivetted to an iron frame h i k l, which is to lay upon the top of the hot-well, and intended to strengthen the pan, being of slight copper, so that, when any thing is to do at the horse foot valve, the frame and pan will lift out altogether.

M—Is the feeding spout for the centre boiler, and if the engine has two boilers, **N** will be the feeding spout for the off boiler.

Q—A branch upon the square frame, with a hole in it to receive the tunnel pipe, which will be further explained in the sequel.

Now, to give the water a degree of warmth before it enters the pan, it is brought from a small reservoir through many yards of lead pipe, immersed in a lander trough, conveying the hot-well water (after having left the hot-well) throughout its whole length.

The lander trough is composed of three deals, and supposed to be eight inches wide, and nine deep, inside measure, made to convey the water of the hot-well by a small descent from the hot-well (suppose about one foot in forty yards) into a little pond or receptacle, from whence the water runs away by a ditch.

In this lander trough is laid a lead pipe of two inches bore, made of sheet lead, turned and burnt, and extending through its whole length, which, being inserted into the wooden trees, bringing water from a small reservoir, containing soft water, will convey it into the feeding pan, and the leaden pipe being all the way immersed in the current of hot water through the lander, will by that means get prepared by having the chill taken off before it enters the pan.

After being further warmed in the pan, it runs off by the two spouts **M N**, whereof the water from **M** falls into the wooden spout, which leads into a tunnel upon a pipe of about $1\frac{1}{2}$ inch bore, which is turned and joined to the upright feeding pipe of the boiler. In like manner, the spout **N** is provided with a wooden spout to convey the feeding water for the off boiler into a tunnel and pipe of the same kind.

The sloping pipe of wood for conveying the hot-well water from the hot-well down to the lander, for the sake of its being out of the way, is proposed to be carried under the timber floor that makes the boiler head floor over the stoke hole, and then passing by the lander.

At the distance of three or four feet, little ribs or bars are to be laid across the bottom of the lander to support the lead pipe from the bottom, that the hot water may get round it, and also to impede the water from running in so swift a current as not to drown and cover the lead pipe.

Now, the end of the lead pipe at the place where the lander trough terminates, being several feet below the level of the top of the hot well, it is necessary that it be joined to the wooden trees coming from the little reservoir, whose bottom, or rather the entry of the wooden pipes, shall be one foot higher than the top of the lead pipe at the cock delivering into the pan.

The little reservoir is supposed to be made artificially, or dug upon such ground that the mouth of the pipe at the reservoir shall be about three feet below the surface of the reservoir when full, in consequence hereof the water will descend through the wooden pipes, and ascend through the lead pipes, and pass by the cock into the tunnel Q, fig. 2, where, descending by the copper tunnel pipe thereto annexed of about two inches diameter, it will gradually ascend towards the surface of the pan, and it passes off by the two spouts to the boilers, as before described.

Besides the two inch cock at the pan, there is proposed a $2\frac{1}{2}$ inch stop cock in the lead pipe, by way of regulation and convenience, as follows:

The little reservoir is supposed to be of sufficient size to hold feeding water for one or more hours service at an extreme; it is then to be found, by a few days trial, what quantity of water continually running from the great reservoir, to be let out by a cock placed in a tree at the bottom, and then passing through a common open cast trench into the little reservoir, will keep it supplied during the twenty-four hours service, and in like manner, the stop cock in the lead pipe must be regulated so as to supply a quantity into the pan equivalent to the boiler's consumption, which being once found, will need little alteration, so that when the engine stops working, there will be nothing to do but to shut the cock at the pan, and when it begins working to open it, the regulation of quantity being done by the stop cock in the lead pipe; there will, however, be just the same attention necessary in the keeper, to see that the water in the boilers keeps right by the gage cocks, as in the common way of feeding, and to give the stop-cock in the pipe a touch accordingly.

It may probably happen that one feeding spout may run less water from the pan than the other, or that one boiler may raise more steam than the other, in which case, if a couple

couple of thin wedges are driven under the iron frame that supports the pan, on the opposite side of that which runs too little, the quantity may thus be adjusted betwixt them as nicely as you please.

If the intervals of working do not exceed half an hour, it perhaps may be found convenient to let the boilers feed at such a rate as to take in the water continually; for though in the interval the water will go into the boilers almost cold, yet the fire that must necessarily be kept on, will keep the whole to a boiling state, that now only produces a loss of steam, and consequently of feeding water.

Lastly, the snift pipe, instead of being carried out of doors, may be returned, and come down into the pan, and its end being bored with several small holes, be immersed about four inches into the pan's water, but not so deep as to prevent its snifting; by this means the heat of the steam of the snifting pipe, that otherwise would be lost, will be added to the feeding water in the pans.

COMPUTATION OF QUANTITY.

A cube yard of water will last an engine of sixty-inch cylinder, in boiler's feed, full eighteen minutes, that is, suppose the engine to go twelve hours in twenty-four, at the rate of forty cube yards per day, a reservoir, therefore, of forty yards square, and two yards mean depth, will last the engine eighty days; and a reservoir of seventy-six yards long, and twenty-six yards mean width, will nearly do the same thing at five feet deep.

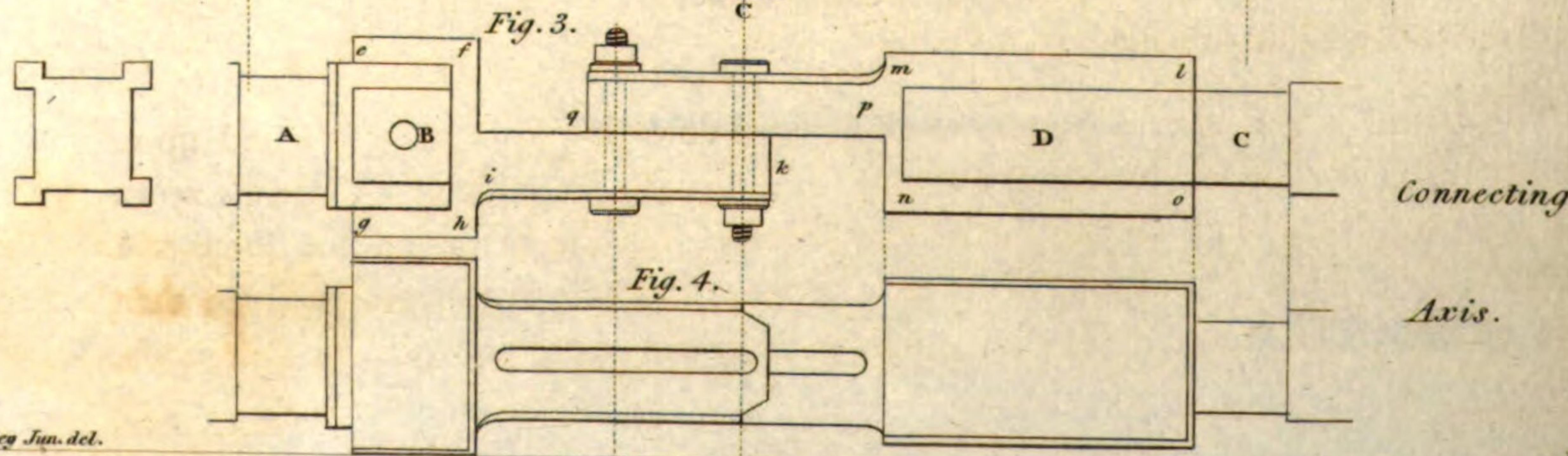
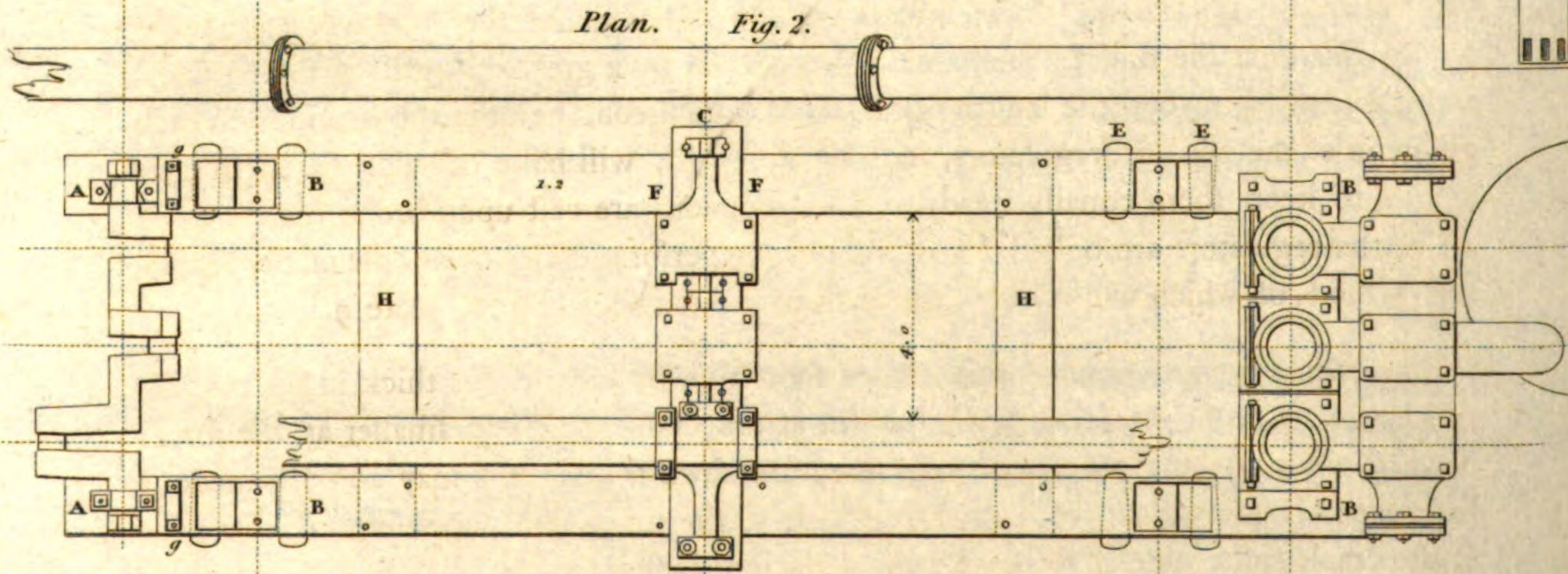
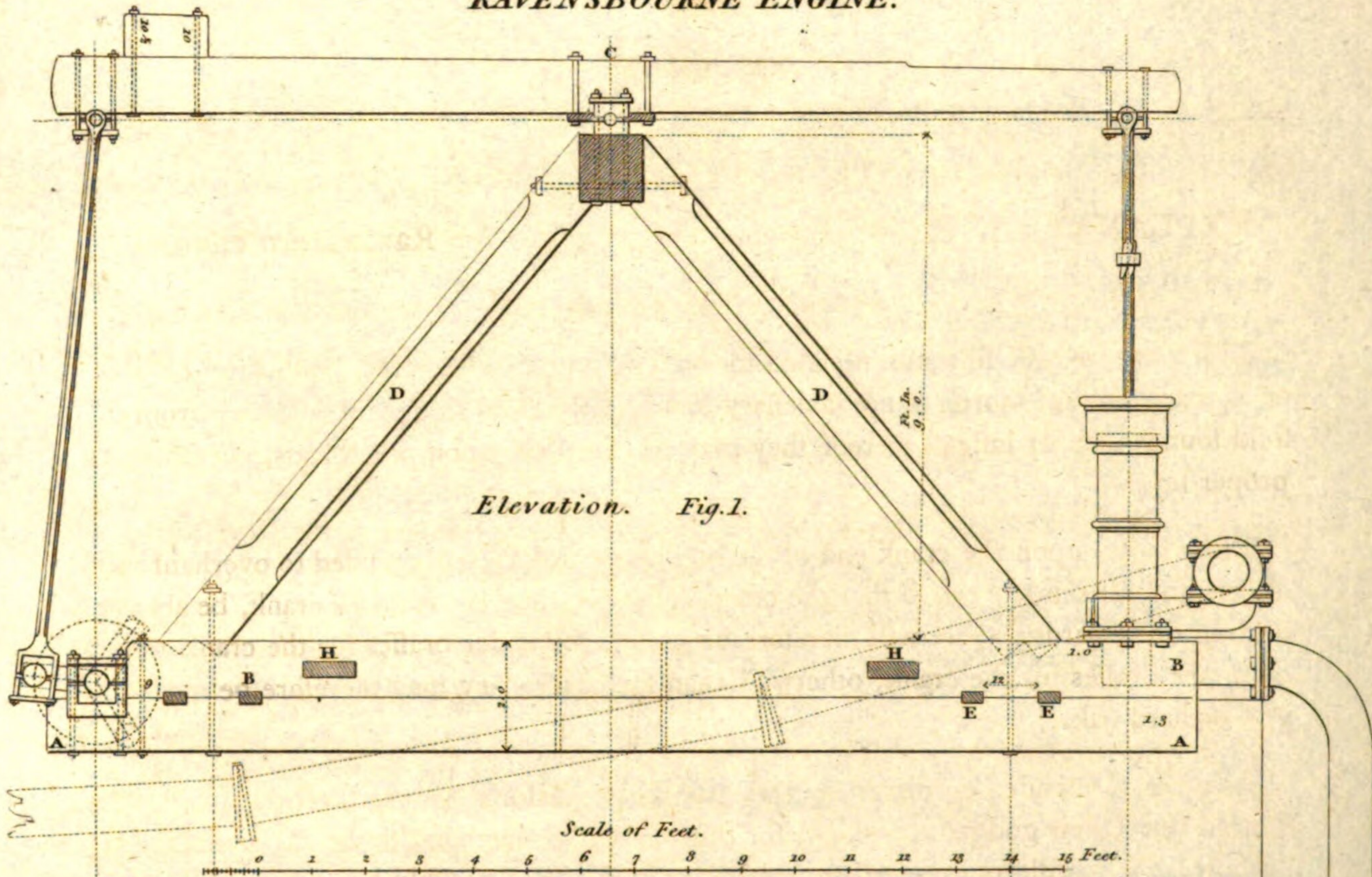
J. SMEATON.

Austhorpe, 8th October, 1779.

P. S. The small reservoir will hold twenty-four working hours water, at eight yards wide by ten yards long, and to draw off a yard depth of water; but it will be well to dig the small reservoir a foot deeper, near the mouth of the pipe, that the water may go in clear of sediment.

RAVENSBURN

RAVENSBORNE ENGINE.



J. Farey Jun. del.

J. Smcaton. 1778.
W. Lowry sculp.

RAVENSBURN ENGINE.

EXPLANATION of the plan and elevation for the Ravensburn engine.

See the design plates 9, 10.

THE two ground fills are intended to be laid upon brick walls, consisting of one or as many courses more, as are necessary to bring them up to a proper level from a solid foundation, or instead thereof they may be founded upon pile heads, cut off to a proper level.

The weights upon the crank end of the regulating beams, are intended to overhaul the forcers and fill the barrels, so that the crank rods will, together with the crank, be always bearing downwards; there will therefore be no use for under brasses for the crank rods, or upper brasses for the crank, otherwise than for safety, they may therefore be made of yew or hard oak.

As there is intended no directing frame for the regulator's beams, their steadiness will depend upon their gudgeons, which, for this reason, are intended to be as far distant as possible; the middle one therefore is made as long as can possibly be admitted between the outward regulators; which shortening the gudgeons of the outward regulators, on the side next the middle one, are compensated by a greater length on the outsides, and is extended beyond the length of the middle gudgeon, because the bearings on each gudgeon of the outward regulators, not being equal, will have occasion for a greater length to keep them equally steady. The gudgeons are cast upon broad plates, upon which the regulators are bolted down, without any perforation in the middle of the beams, the method of which will readily appear from the drawing, fig. 2, plate 9.

The regulators are supposed to be one foot high by nine inches thick in the middle, and to be made so much bigger in height at the crank end, and smaller at the forcer end, as will suit the taper of the trees they are sawn from; they may also be made a little taper in the width if it be found suitable to the times, viz. suppose ten inches wide at the crank ends, nine at the gudgeon, and eight inches at the forcer, I mean them however to be all three alike.

The centre or axis of each barrel, when screwed down in place, may be found upon the regulator when level, by laying a straight rule against the inside of the barrels up to the regulators, and then finding the middle between, but the centre of the force rod brasses must be set four-tenths of an inch further from the regulators gudgeon than this middle point, because the curve, described by the centre point of the force rods,

will

will be eight-tenths of an inch out of a straight line, and by doing it this way, will never depart from the middle line, but four-tenths of an inch on each side, which will avoid the necessity of arch-heads and chains, as I had first intended.

I propose that every part of the engine may be put together, and in working condition, in the yard, before any part of it is removed to the engine house.

N. B. The nuts for setting down the gudgeons upon their brasses, are intended to be hexagons, because if square in turning round they will interfere.

Every gudgeon is intended to have its own separate pair of brasses, but those between the regulators will be close together; the regulator in the plan, fig. 2. that is, furthest from the upright view, is shewn in place as completed, but the ends broken off, the other two are supposed not in place, but the lower brasses in place ready to receive them.

The working barrels shewn in plate 10, fig. 3, is a plan of the whole, and fig. 2, is the section of the middle working barrel, as also of the horse tree, with the suction pipe, and of the saddle tree or chest.

AB is the cylindrical part of the barrel, or bored part of the forcer, of ten inches diameter, below which it widens to

CD, the chamber for the suction valve, and conveyances of twelve inches diameter.

EE shew the flanch or square base upon which it stands, being eighteen inches square.

FF is the upper face or seat of the horse tree, which has three round holes of eight inches diameter, denoted by

GG, which are covered by the suction valves.

HI is the communication pipe of the horse tree, being eight inches square, and carries the water to all the three barrels.

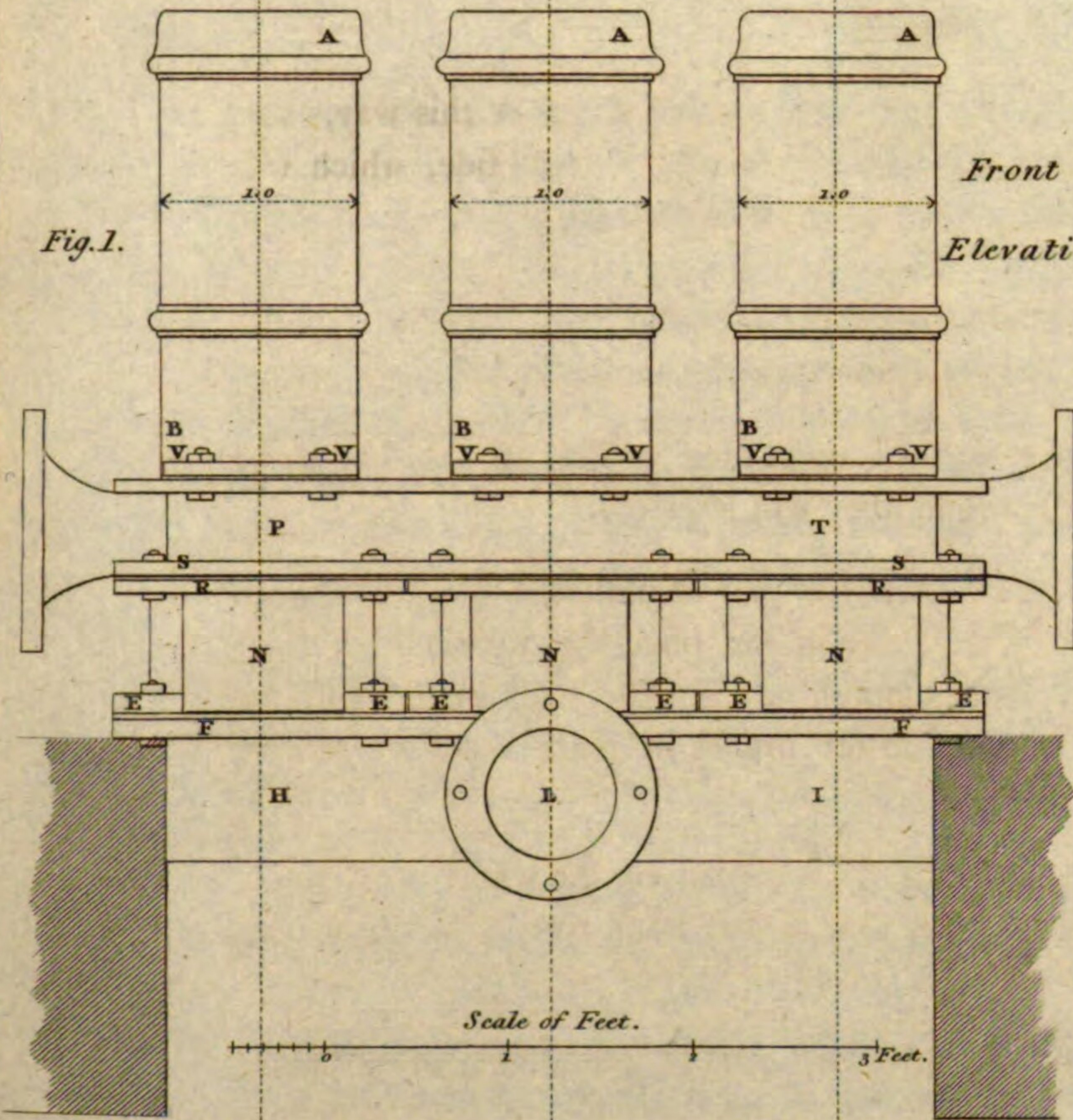
KL is the suction pipe and flanch, which is round, and of eight inches diameter, placed answerable to the middle barrel only.

MMN OO shew the branch or conveyance pipe, one to each barrel, the entry MM and passage to N are square, that is, eight inches wide by six high, but gradually gathered

DESIGN FOR THE WORKING BARRELS FOR RAVENSBORNE ENGINE.

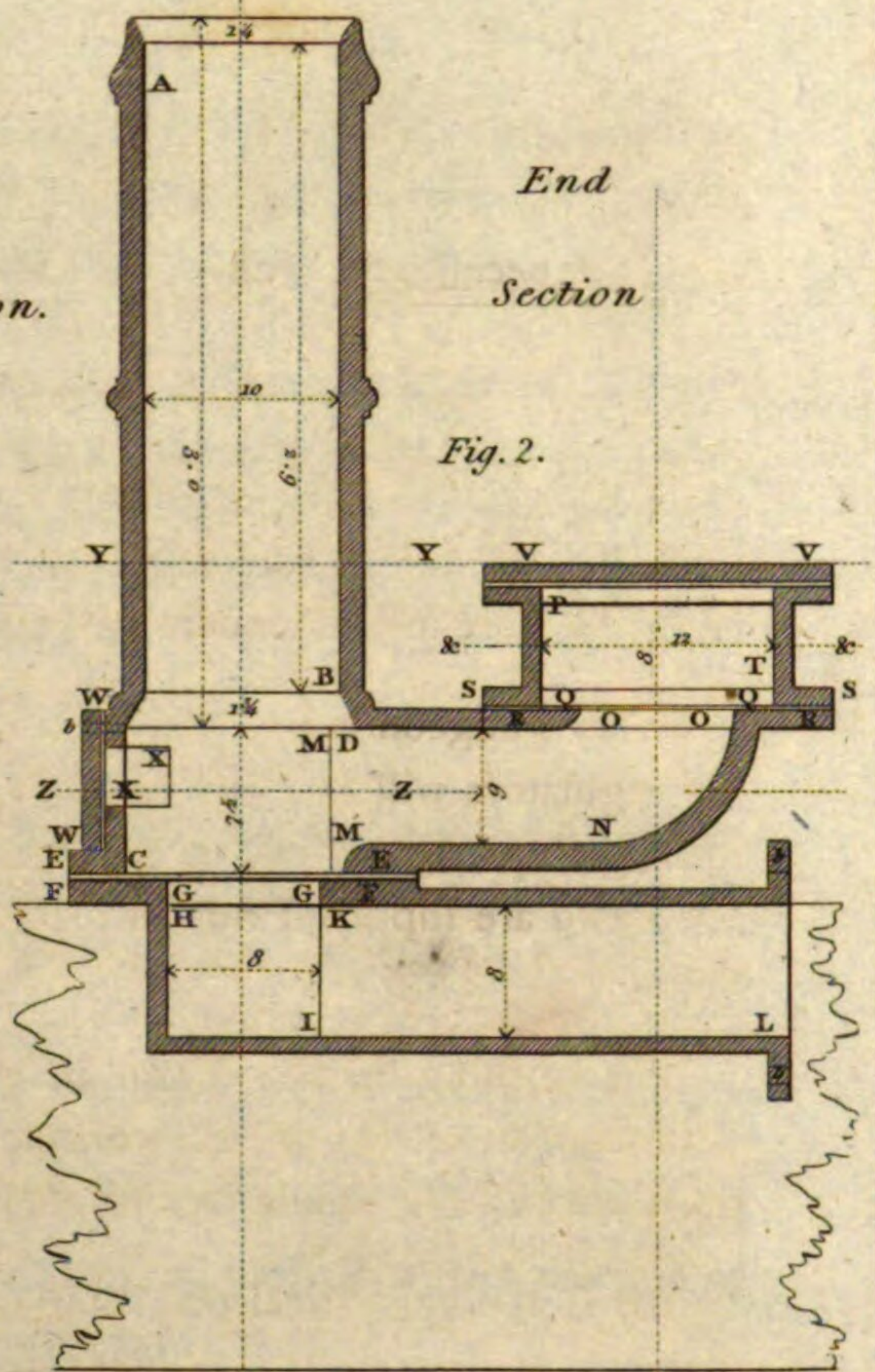
Fig. 1.

Front
Elevation.



End
Section

Fig. 2.



Plan. Fig. 3.

Pl. In.
5. 5. Long.

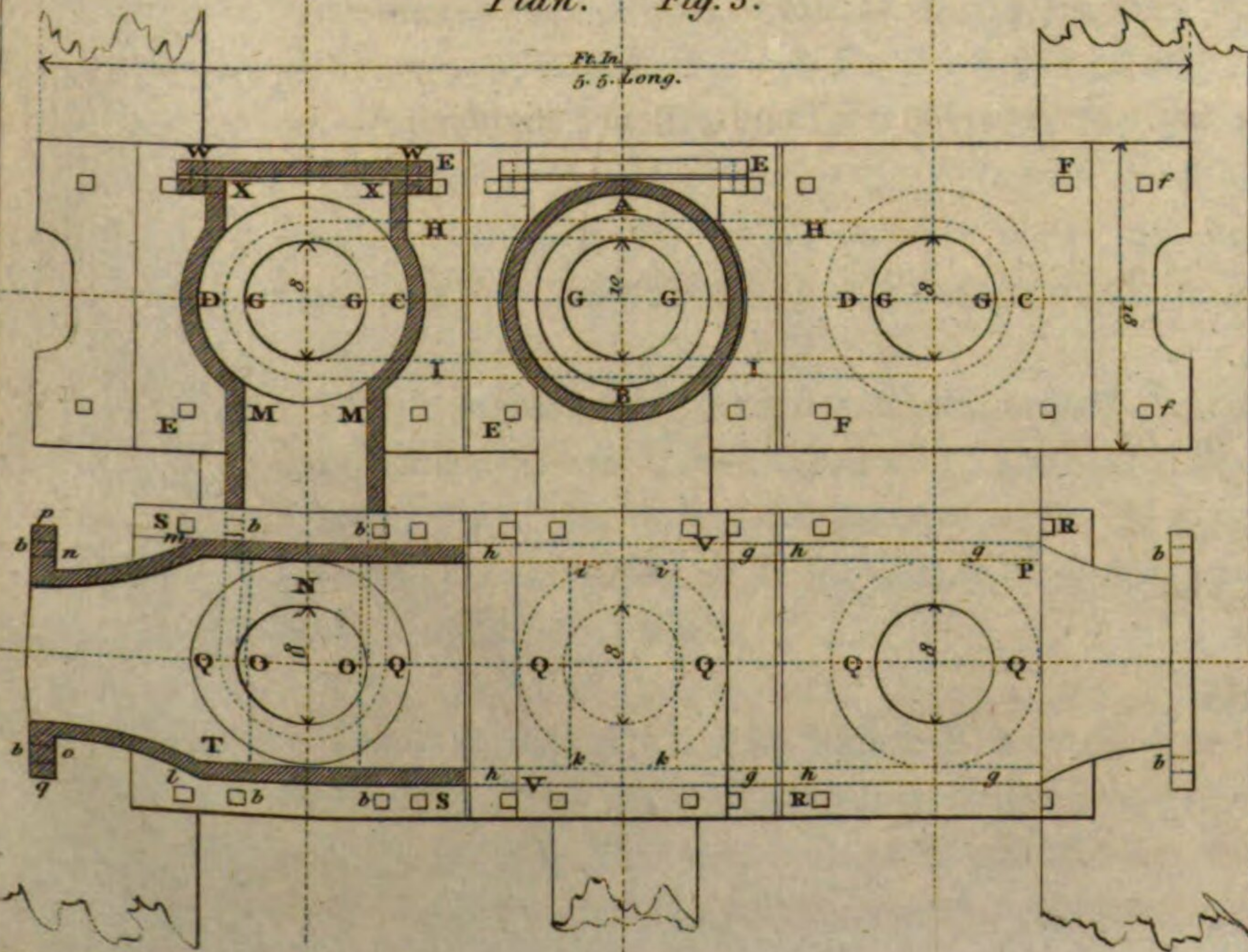
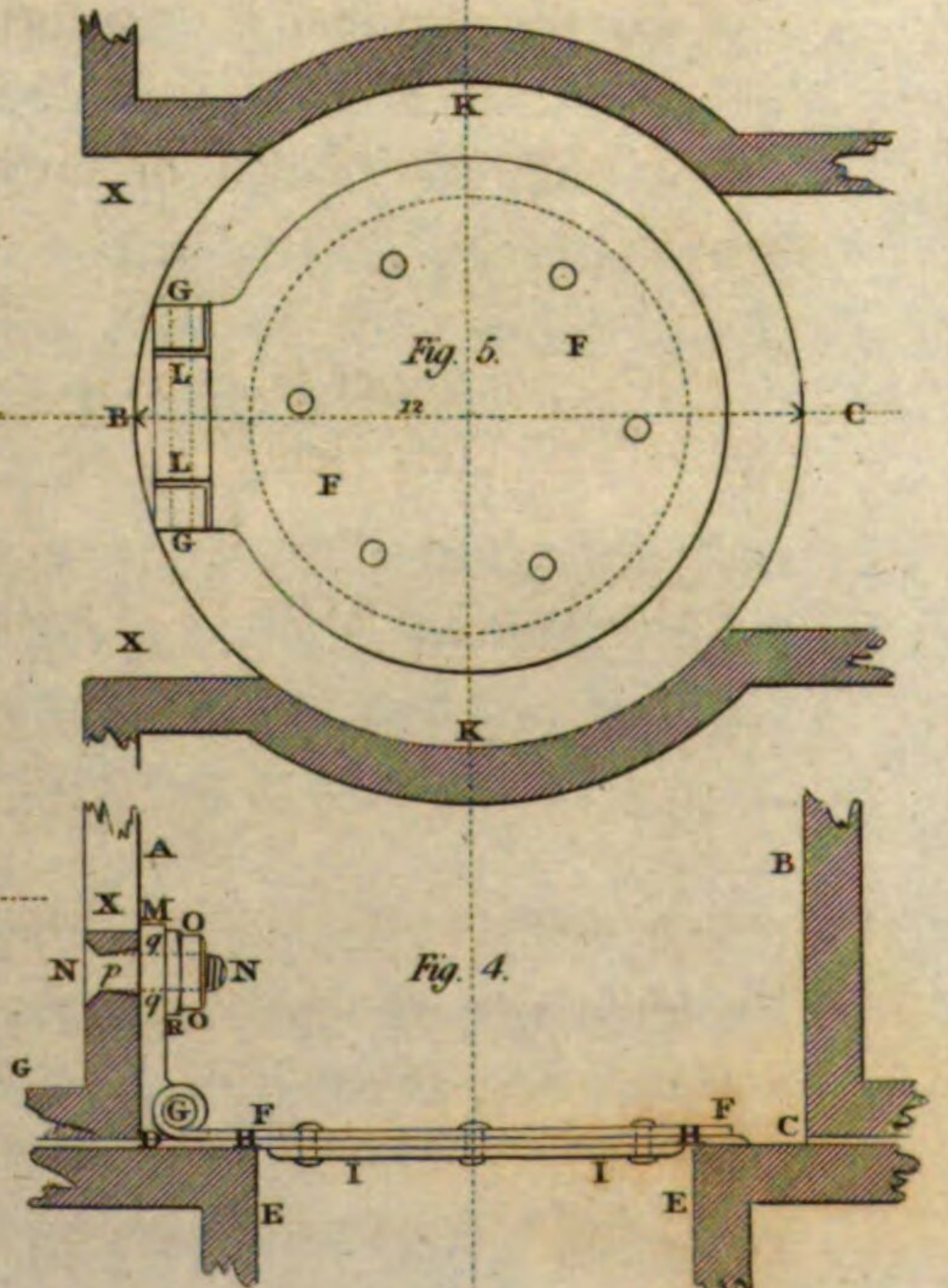


Fig. 4.



J. Farey Jun. del.

J. Smeaton 1778.
W. Lowry sculp.

gathered into the round hole *OO* of eight inches diameter, through which the water is forced into the cavity of the chest or saddle tree *P T*, twelve inches wide, and eight inches high, which, like the horse tree, communicates with all the three barrels.

The hole *OO* is covered by the forcing valve, and this is in the middle of *RR*, a flanch of eighteen inches square, upon the branch of each barrel, so that these three flanches of the three barrels form a seat to which the under face of the saddle tree applies itself, and fixes by the flanches *SS*, this under face being perforated in three places with a round hole of twelve inches diameter, marked *QQ*, surrounding each valve, and concentric with the hole *OO*.

Directly over each valve, in the upper surface of the chest, is a perforation of twelve inches length, equal to the width of the chest, and six inches wide, each covered with

V V, a flat lid serving to look at, and take in and out the valves separately, without unscrewing the chest, and with the same intent.

W W represent a door closing the opening *XX*, of nine and a half inches wide, and three inches high, by which the suction valves are got in and out.

So far the same letters explain both figures, but for a more full explanation of the plan fig. 3. observe that *ff* *FF* shew a part of the upper face of the horse tree, without a barrel upon it, the part *FF* shewing the place for the base of the barrel, the dotted lines *HI. HI.* shewing the figure of the square communication pipe under the same, the sucking pipe lying directly under the branch pipe of the middle barrel, cannot here be represented, but is sufficiently so in the section fig. 2.

In like manner *RR* shew one of the naked flanches of the barrel's communication pipe, cleared of the chest; upon which the dotted lines *gh. gh.* shew the place of the sides of the chest, with the manner of their being gathered into an eight inch round hole and flanch at each end, for joining the pipe of conduct at either end, the other being shut by a flat plate.

The middle barrel *AB* is supposed to be cut by a horizontal section upon the level of the line *YY*, fig. 2. consequently the whole respecting it is shewn as put together

with the lid V V in place, the dotted circle Q Q shewing the round hole in the bottom and i k i k the square hole in the top of the chest, that is shut by the lid at V V.

The near barrel C D X M is represented by a horizontal section through the middle of the chamber, according to the level of the dotted line Z Z in fig. 2. and the area S S is shewn as things would appear upon an horizontal section through the middle of the chest upon the level of the dotted line & & in fig. 2. but l m n o p q represent that end of the chest gathered into a circle and flanch as it will appear from above when finished.

N. B. The whole length of the horse tree, and of the chest or saddle tree (each being in one piece) is five feet five inches.

The small squares shew the bolt holes, and the places of bolt holes shewn by dotted lines are all marked at b.

In the section fig. 4,

A B C D represent a section of the chamber where the valves lie, being twelve inches in width.

E E is the inside width or diameter of the opening of the clack seat, being eight inches diameter.

F F is the upper plate of the valve, being about nine and a half inches diameter, but branching out on one side, so as to form a hinge or tankard lid joint at G.

H H is the leather of thick dintle, and ten inches diameter.

I I is the under plate to be rivetted by about six rivets in the circumference, and one in the centre.

X is the perforation to introduce the valve covered by the clack hole door.

In the plan fig. 5,

K B K represents a part of the circumference of the chamber, on the side where the hinge is applied, so that the line B C in the plan will correspond with the line B C in the section.

G G will be the centre, or axis of the hinge, whose middle part L L, is in breadth two and a half inches, and is formed from the upper plate of the valve.

G L G L unite in one above the joint, and rise up as in

The section.

G M is the rising part of the hinge by which it is fixed by

N N the bolt, and

O O, the nut; this bolt may be about five-eighths of an inch diameter, and pass through a round hole at p to be bored in the flat side of the chamber; but the chamfered head at N, being sunk in square with a chisel, will prevent the bolt from turning round while the nut O O is tightening, and the hole for this bolt must be bored sufficiently near the perforation X that its head may be covered, and secured from leakage by the clack-hole door.

The rising piece G M must be adapted on the outside to the curve of the chamber, but the inside flat; the hole in the rising piece, by which the bolt passes through it, must be at q q, a full eighth of an inch on a side wider than the bolt, that the valve may fairly seat itself, and find its own place, and will be firmly fixed by the counter plate R.

N. B. The center-pin of the joint must be full one-sixteenth of an inch less in diameter than the holes in the lid and ear-pieces, nor must the joint between the lid and ears be close, so that the valve may be at free liberty to seat itself according to the pressure of the water; and that it may not be confined from settling as the leather wears thinner; the rising piece must be pushed down as far as it will easily go, and then there will be all the liberty given that may be for the valve to settle without confinement; indeed it would be better if the holes in the joint were made a little oval, both in the lid and ears, the long way of the oval to be in a vertical position, and as the centre pin is expected to wear the most of any thing, it would not be amiss to make it of steel, but not tempered, so that a little brass ring or collet being put on at each end, they may be rivetted to keep it in place, in which it should have no confinement either endways or sideways.

The only thing to be attended to, in respect to the tightness of the joint is, that its
vacillation

vacillation sideways shall not be sufficient to bring the under plate of the valve upon the seat, so as to prevent the leather's coming to a fair bearing; but to prevent all possibility of this, the under plates may be made a little oval, so that sideways they may not be above seven inches in diameter.

The above particularly describes the valves for the barrels, the forcing valves will not differ, except from the circumstances of the chambers being square, and the doors being at the top, which will require the rising piece to be flat, and the head of the bolt NN, instead of being chamfered and sunk in, to be a broad flat head, so as to admit a piece of leather under it on the outside to make it water tight.

J. SMEATON.

Austhorpe, 6th June, 1779.

The corner-pin of the joint must be full one-fifth of an inch less in diameter than the holes in the lid and ear-pieces, not must the joint between the lid and ear be close, so that the valve may be at free liberty to seat itself according to the position of the water; and that it may not be constrained from seating as the leather wears, the rising piece must be pushed down as far as it will easily go, and then there will be no liberty given that may be for the valve to settle without confinement. Indeed it would be better if the holes in the joint were made a little oval, both in the lid and ear, the long way of the oval to be in a vertical position, and as the centre of the oval is not the most of any thing, it would not be amiss to make it of steel, but not tempered, so that a little bending or collar being put on at each end, they may be forced to keep in place, in which it should have no confinement either way or sideways, and every time the joint is opened it may be attended to, in respect to the tightness of the joint is, that its

SEACROFT

SEACROFT COKE FURNACE.

The REPORT of JOHN SMEATON, engineer, concerning the powers necessary for working a coke furnace at Seacroft.

THE whole rise, as per level taken by Mr. Eastburn, from the tail of the colliery drain to the surface of the mill pond at a full head, is thirty-three feet four inches, and there is reason to suppose, from observations since made, that by pursuing Mr. Porter's drain, there will be a loss of level of two feet; our neat difference to work upon will therefore be thirty-one feet four inches, upon which fall, to allow for a sufficient head and clearances, let us for the present suppose the water-wheel to be overshot of twenty-eight feet high, and upon this height, by calculation drawn from my experience, to work a coke furnace roundly, that is, at a middling speed, will require 7,294 tons of water per day to be expended upon it.

I also calculate, that this quantity of water expended upon the present corn mill will grind corn at the rate of three bushels, or a load per hour; it will, therefore, follow, that for so much of the year as the natural supply of water will keep the present mill going, so as to grind at the rate of a load per hour, so much of the year this natural supply may be expected to work the furnace as above mentioned without any foreign aid, and this information the proprietors will the most naturally get upon the spot. From what has occurred to me upon the subject, I should state it as follows:

That for five months in the year there will be a full supply of water to go on continually at the rate above mentioned, which will give	5 months' water.
That for three months more there will be as much as will give two-thirds of the quantity requisite, which will amount to	2 months' water.
And that for the other four, there will at an average not be more than what will cause the mill to go six hours in twenty-four, which will amount to	1 month's water.
The furnace may therefore expect to have yearly	8 months' water.

Now, though the average of the four dry months is stated at six hours water, yet it frequently happens, that for three months together the natural supply does not amount to above three hours water per day; so that without some subsidiary power, this furnace must undoubtedly blow out every summer, and this subsidiary power I advise to be a fire engine, and that of sufficient power to work the furnace at the above rate, independently

pendently of the natural supply, for when the natural supply is too scanty to work the furnace, the engine being set a-going will work till the natural supply has filled the ponds, and then the engine may cease working, and save fuel till the ponds become empty again; or the natural supply may be employed at the boring mill, even at the scarcest time.

The whole quantity then, 7294 tons per day, I can engage to raise back by a fire-engine of no more than a thirty-inch cylinder, and this engine I can warrant will work with three cwt. of coals per hour, that is, seventy-two cwt. per twenty-four hours, of the quality of the late Halton Bright, that is, if we allow $2\frac{1}{4}$ cwt. the horse pack weight to each corf, this will amount to two dozen and eight corves per day. The quality of the coals wherewith this engine will probably work is unknown to me; but in proportion as they are better or worse engine coals, the consumption will be greater or less; but this engine would be worked with about eighty-six cwt. of raw fleck per twenty-four hours, such as were used to be led from the fleck heap to the engine at Halton; and if we allow the same weight and measure to the dozen of fleck, as of coals, this will be no more than three dozen two corves of fleck per twenty-four hours, which, if laid down at the engine door, at 1s. 6d. per dozen, the engine will work at the price of 3s. 3d. per day in fuel, more or less, as the fleck (or small coal) will be procured and laid down at the engine door for more or than less 1s. 6d. per dozen.

Now, if the engine is worked four months in the year, at the rate of 3s. 3d. per day, the whole amount of the fuel will be only £19 16s. 6d.; but this likewise will be more, if the engine is worked longer than the whole four months, either on account of the defect of the natural supply, or to keep the boring mill at work; or if done at many different intervals, an addition will be required to make the water boil each time of lighting the fire.

The engine will be attended by one man, when its work can be done in twelve hours, and by two men when working twenty-four hours: when it wants leathering, the wright of the works will be wanted to assist, and when not used, the engine-keepers will be employed in other labouring work.

J. SMEATON.

Austhorpe, 16th January, 1779.

DRAWING

DRAWING COALS BY HORSES AND BY ENGINE.

Comparative ESTIMATE of drawing coals by horses, or by a coal engine worked by water supplied by a fire engine.

ESTIMATE by horses.

	£	s.	d.
The pit eighty-two fathom, to draw a corf in two minutes for twelve hours per day, will take nine horses at £25 per annum each horse, - - -	225	0	0
To two gin drivers, at eight-pence per day each, six days per week, is eight shillings per week, and fifty weeks per year, is - - -	20	0	0
To one horse keeper, at one shilling per day, the whole year, - - -	18	5	0
Charge of a pit drawn by horses, - - -	263	5	0

ESTIMATE by the water coal engine.

Suppose the fire engine to cost £500, and the coal engine £300, in the whole £800, for which, allowing £10 per cent., will be per annum, - - -	80	0	0
Coals, nine bolls per day, at four-pence, that is, three shillings per day, and for six days per week, eighteen shillings, and for fifty weeks per year, - - -	45	0	0
A boy to attend the coal engine, at nine-pence, six days per week, and fifty weeks per year, is 300 days, - - -	11	5	0
An engine keeper for the fire engine, at eight shillings per week upon the whole year, - - -	20	16	0
The engine wright's attendance on the two engines, at sixpence per working day, 300 days per year, - - -	7	10	0
Charge of a pit drawn by a water coal engine, - - -	164	11	0

N. B. It is expected that the wear and tear of horses and gins will be greater than that of the fire engine and water engines.

J. SMEATON.

Austhorpe, 14th August, 1776.

Mr.

Mr. WESTGARTH's ENGINE.

The REPRESENTATION of JOHN SMEATON, engineer, concerning the Hydraulic Engine, invented by Mr. WILLIAM WESTGARTH, of Coal Cleugh, in the county of Northumberland, for raising water by water.

Mr. SMEATON begs leave to advertise his friends and acquaintance, as well as those who are desirous of promoting the success of good mechanical inventions, that they will find the engine, the model of which will be exhibited by Mr. Westgarth, to be highly worthy of their attention and regard, being, in his opinion, one of the greatest strokes of art in the hydraulic way that has appeared since the invention of the fire-engine.

This machine is founded on one of the most simple principles of statics, viz. that of a heavier column of water pressing up, or raising a lighter; an idea which, though proportionably obvious as it is simple, and therefore far from new, having been adopted by several able and eminent mechanics, yet it has been reserved for Mr. Westgarth to form the proper expedients, and obviate those difficulties which attended the practical execution of machines intended to work on this principle, and which contrivances are (as to my knowledge) not only new and peculiar to Mr. Westgarth, but which alone have contributed to its success, and, therefore, though the whole composition dependent thereon is highly deserving of a patent, or exclusive privilege, yet Mr. Westgarth choosing rather to communicate his invention to the public, seems the more highly deserving of the public, and of the patrons and encouragers of arts for that very reason, and he seems still the more worthy of proper notice, as he has not been hasty in communicating his invention till the value thereof has fully appeared by a number of engines built at large, and applied to real use.

Independently of the various drafts, experiments, and essays on models, which I am informed Mr. Westgarth had in hand for years past prior to his attempting a machine in large, I had the pleasure of seeing the first complete machine of this kind at work for draining or unwatering a lead mine belonging to Sir Walter Blackett, at Coal Cleugh aforesaid, in the summer of 1765, since which time that machine has been shewn to all those who had the curiosity to see it; he has now erected four others in different mines in that neighbourhood, one of which I have seen, and all attended with
great

great success, as I have much reason to believe, not only from the nature of the construction, but from the reports of those for whom they have been erected.

This machine is not only peculiarly adapted for the raising of water by water for draining of mines, but the same principle can readily be extended to the raising of water for supplying towns, gentlemen's houses, &c. and universally for raising water from any depth wherever a fall of water can be procured, and particularly in those cases where the fall is great, that is, where it exceeds thirty or forty feet, it will (in my opinion) not only exceed all other known machines, in effect, but in simplicity, and that whether the quantity of water that is to be applied be great or small; I, therefore, think that this machine is not only very curious in itself, but will be of great advantage to the public.

CORN MILL, TO BE WORKED BY A FIRE ENGINE.

To the Honorable the Commissioners of His Majesty's Victualling-Office.

GENTLEMEN,

IN compliance with your order of the 14th May last, desiring me to give my opinion, which of the two methods I prefer of constructing a mill, to be worked by steam, (one by the intervention of water, the other by a crank), and the reason of that preference, and to give in a plan of such a mill as I would recommend, of sufficient power to grind 400 quarters of corn per week, I have fully and duly considered the business, and find that in point of quantity of coals to be consumed for raising a power sufficient to do this business, supposing a machine in either way perfectly understood, there will be no material difference; but in point of convenience and good effect in the practical part, it appears to me that the difference will be very considerable; for, in the first place, I apprehend that no motion communicated from the reciprocating beam of a fire engine can ever act perfectly equal and steady in producing a circular motion, like the regular efflux of water in turning a water-wheel, and much of the good effect of a water-mill is well known to depend upon the motion communicated to the mill-stones being perfectly equal and smooth, as the least tremor or agitation takes off from the complete performance.

Secondly, all the fire-engines that I have seen are liable to stoppages, and that so suddenly, that in making a single stroke the machine is capable of passing from almost the full power and motion to a total cessation; for, whenever the steam gets lowered in its heat and elasticity below a certain degree, for want of a renewal of the fire in due time or otherwise, the engine is then incapable of performing the necessary functions for preserving its motion. In the raising of water, (a business for which the fire-engine seems peculiarly adapted), the stoppage of the engine for a few strokes is of no other ill consequence than the loss of so much time, but in the motion of mill-stones grinding corn, such stoppages would have a particular ill effect.

When a water-mill stops for want of water, the motion is lost by degrees, and the feeding of the mill-stones with corn depending on the rapidity of the motion, ceases also gradually, so that when the mill is set a-going again, the stones not being full-charged with corn, there is no impediment to their being set forwards, and in like manner,

manner, when the mill is stopped by the shutting down the sluice, the miller, being apprised of his own intention, takes off the feed of corn, so that by such time as the mill stands still, the stones are in a great measure cleared; but if a mill in full work were to stop in the time of a single stroke of the engine, it would stop with the stones full-charged with corn, for the miller could not be apprised thereof, so that before the motion could be renewed, the stones must be raised from their grinding bearings, in which case a quantity of half-ground meal would come through before they could be re-adjusted to their work, and which could never be done till they had acquired a regular speed, which would take up some time, when immediately deriving their power from the reciprocating motion of a fire-engine.

It is true that much care in the engine-keeper may prevent frequent stoppages, but no one can be expected to be so much upon his guard that this shall never happen, and if it were to happen but once in twelve hours, it would confuse the regular operations of the mill to such a degree, as to render it very disagreeable to those concerned in the working of it, as it would generally happen when they were not aware of it.

By the intervention of water, these uncertainties and difficulties are avoided, for the work, in fact, is a water-mill, and as in the construction here presented, there will be a sufficiency of reservoir or mill-pond, capable of keeping it going one minute without sensible abatement, it seldom happens that if, by any inadvertence of the engine-keeper, the engine stops, but that in less than a minute, and generally in less than half a minute, he can set it a-going, so that the mill will regularly continue at work, and if any thing should go wrong with the engine for a greater length of time, as the mill will stop gradually, no particular derangement can happen, further than so much loss of time, as the miller will always be apprised thereof by the gradual loss of the mill's motion.

For these reasons, were I to establish a work of this kind at my own cost, I should certainly execute it by the intervention of water, and therefore must greatly prefer it.

In putting a design of this kind into actual execution, so as *bona fide* to dispatch 400 quarters of corn in a week, it is necessary to make a provision of power beyond the bare calculation, to allow for necessary and unavoidable stoppages, and to bring the water round into the reservoir again; for this reason I have estimated the work to be dispatched in about twenty hours a day, and seven days to the week, in which case it will

will be proper that the engine should be of sufficient power to raise 460 cube feet of water per minute, to the height of thirty-four feet.

The size of the engine necessary for this business, and the quantity of coals to work it, will be ascertained by Messrs. Bolton and Watt, as well as the proper construction of the engine.

I am, gentlemen,

your most obliged,

Austhorpe, 23d Nov. 1781.

and most humble servant,

J. SMEATON.

GOSPORT WATER WORKS, &c.

To the Honourable the Commissioners of His Majesty's Victualling Office.

The REPORT of JOHN SMEATON, engineer, upon the state and distribution of the waters at the brewery at Weevill, near Gosport.

HAVING carefully viewed and examined the state of the waters at this establishment, in regard to their practicability of furnishing an ample, lasting, and certain supply, not only for the two breweries working there, and such further additions in that branch as may be thought necessary; but also for watering such large fleets of his majesty's ships as may have occasion to lie at Spithead; I have principally observed as follows:

That the new well lately dug there, furnishes the highest degree of probability, that from this alone the whole supply which can possibly be wanted, will be amply furnished, when a proper engine is fixed thereon, by which the water can be conveniently raised and distributed; for this reason I cannot hesitate to recommend to the board to construct such machinery, reservoir, and pipes, as may be capable of effecting this business, leaving whatever has been constructed before by way of furnishing a part of the water wanted, in its present state, so that if necessary, the same part may still be supplied by the same means as heretofore.

I understand, that so large a fleet as has lately been at Spithead, has been frequently in want of a supply to the amount of 200 tons of water per day; the brewery at present consumes to the amount of 85 tons, and if this quantity should be wanted to be doubled, the brewery would then take 170 tons, which, with the shipping, will create an occasional want of 370 tons per day.

At present there are no means of raising the water from the new well, but by a hand pump, which, when worked continually, has never been able to lower the surface above five or six feet, the total depth in water being twenty-seven feet. The quantity therefore that it may be capable of furnishing, by no means appears from this reduction, but may be judged of by a consideration of the following facts:

That when the auger by which the bottom was bored, pierced through the stratum of clay in which the well is sunk, into the stratum of sand which affords the water, at
which

which they arrived sooner than expected, the water came in so fast upon them, that they were obliged to clear the well, and it was observed, that within the space of six hours, it rose twenty feet perpendicular; the cubic content of which cavity being full forty-eight tons, it follows, that the average rate of supply was full eight tons per hour, or at the rate of 192 tons per day; but as the utmost height to which it will rise, but little exceeds twenty-seven feet, it must be supposed that the rise of the surface was much slower, when the well had got twenty feet depth of water, than at first, when there was so much less pressure upon the rising column; so that when an engine is placed thereon, capable of clearing and keeping clear the well of water, that its influx would be at a much greater rate than the average quantity of eight tons per hour, above stated.

The certainty of this increase appears from the facts that attend the Cooperage well, from whence the supply has heretofore been drawn, and which, in many respects, appear similar to the facts that attend the new well.

When the water of the Cooperage well has been drawn out by the horse machine (not long since erected upon it) after standing fourteen hours it gets twenty feet depth of water, on setting the machine to work, it draws out in three hours the twenty feet, together with the growth of water that is continually coming in while the other is drawing out, and which together amounts, by my computation, to forty-nine tons; after this, as I understand the practice is to let all stand for five hours, and then work the machine again as before, and in two hours they again drain the well, we may therefore suppose, that in two-thirds of the time they draw two-thirds of the quantity, and this will amount to $32\frac{2}{3}$ tons, all then again stands for fourteen hours, including the night, and the well fills as before to twenty feet, in this way the quantity drawn per day, or twenty-four hours, will be $81\frac{2}{3}$ tons.

Now the cubic capacity of this well, filled in twenty-four hours, twenty feet high, being measured, I make to be thirty-five tons, that is, it comes in at the average rate of two and a half tons per hour; but the quantity drawn out of the well, after standing five, and working two, in the whole seven hours, it affords, as before stated, $32\frac{2}{3}$ tons, which will be at the rate of $4\frac{2}{3}$ tons per hour, that is, almost double of the average rate of rising twenty feet; so that if instead of working twice in twenty-four hours, as above specified, which, I suppose, in ordinary, may be both convenient and sufficient, yet, if upon an exigency the well were emptied four times in twenty-four hours, at regular and equal intervals, as the surface would then never rise above ten feet,

feet, I am satisfied it will afford an average of five tons per hour, that is, 120 tons in twenty-four hours, instead of $81\frac{2}{3}$ as at present.

Hence taking it for granted, that in like manner the New well will afford double the average quantity of water, if constantly kept low, to what it does in rising twenty feet, it will follow, that the New well thus worked, will afford sixteen tons per hour, a quantity more than equal to all the occasions that are computed to be wanted.

To render this supply still more ample, and therefore certain, as I apprehend that the influx of the water through the bore hole must be in part resisted by a column of sand that will necessarily introduce itself into the bore hole along with the water, I would advise, when a machine is established, capable of drawing out the water, to make four auger holes more, round the circumference of the well, which, giving the water more vent, will in effect lessen the obstruction, and probably increase the quantity of water, but in every event will render the supply more certain, as a single hole is liable to accidental obstructions, by extraneous matter getting into it, which may be lodged in the stratum of sand which supplies the water.

On making trial of the New well's water, I do not find the least difference between that and the Cooperage well, which I understand has been long used and approved, nor indeed do I find any material difference amongst all the waters of that part of the country; even the fine clear stream that falls into the head of Portsmouth harbour, at Fairham, is quite as far from the perfect softness of rain, or distilled water, as the New or Cooperage well; and the well called the Fortune, from whence the water is forced through pipes for the service of the town of Gosport, appears to me just the same. In reality, I apprehend the stratum of sand, which lies at different depths under a bed of clay, extends itself over a considerable part of that flat country, the water which it affords being nearly the same to all.

That the water of the New well and Cooperage well proceed from the same body or source, thus appears, for, notwithstanding that at the New well they pierced the water stratum to a less depth by twenty feet than at the Cooperage well, and though the rate of its influx is in very different quantities, yet the ultimate height to which they all rise is nearly the same, viz. to near upon the level of high water mark at common spring tides, and the ultimate height to which the New and Cooperage wells rise, is in fact, as near as I can measure them, precisely the same.

An engine therefore capable of raising 400 tons per twenty-four hours, out of the New well, will either perform the whole service or drain the well, and if the New well should happen to fall short by reason of any unforeseen intervening circumstance, yet as the Cooperage well will independently furnish 120 tons per day in addition, as has already been shewn, the machinery already upon it can be occasionally used, or the two waters may be united under ground, according to the idea of Mr. Whitbread, by an adit or drift of communication.

That the drawing out of the water of one well, will not materially affect the quantity to be drawn from the other, appears from this circumstance; that when I was there, the New well attained its utmost height when the Cooperage well was drawn empty, which, indeed, seemingly contradicts the idea of their having one common source; but it is to be considered, there is no open communication between them like that of a pipe, but only by the interstices of a mass of sand common to both; each therefore gets its water from the pores of the surrounding mass, and were there two wells at the distance of five yards, instead of 500 feet, as the case is, I doubt not but that the emptying one would lower the water considerably in the other, and though the water percolates very slowly through a bed of sand, when the distance is considerable, yet as the water drawn from it can never rise higher than the level of its source, it will still follow, that equal ultimate heights point out the identity of the source.

At present the water is raised into a small reservoir upon the surface of the ground at the Cooperage well, from whence it runs through elm pipes, and supplies at pleasure the quay reservoir, from whence the water is taken into casks for the shipping; when not wanted there, it runs into the new brewhouse well, whose water, by an underground drain, communicates with the great reservoir, and also with the old brewhouse well; the surfaces therefore of these three are always upon a level, and the conveyance of water into the new brewhouse well, is in effect conveying it into the reservoir. From these wells and reservoirs, the water is again raised by horse machinery into the liquor backs of the old and new brewhouses, to the height of twenty-five feet for the old, and thirty feet for the new brewhouse.

Now I find, if the water be raised at the New well into a reservoir or back, but sixteen feet higher than it is already raised at the Cooperage well, that it will then run by pipes into, and supply the liquor backs of both the present brewhouses, and a new one if required, without pumping, which will be a great easement to the horses used there, as I understand a couple of horses additional are put on whenever they raise the liquor,

liquor, and I find that a proper engine constructed at the new well, will perform the service mentioned, with two horses at a time, the same as used at the Cooperage well, and when the water is not wanted to be raised into the new well reservoir for the supply of the breweries, or otherwise, the water need not be raised higher than the surface of the ground, where it will pass off to the quay reservoirs as fast as it is raised, or on special occasion, by having ready filled the proposed reservoir at the new well, which I intend to hold about eighty tons; this may in fifteen minutes be transferred into the quay reservoir, so that it is scarcely possible to conceive any emergency can happen, that the proposed establishment will not be equal to; whereas at present, when the quay reservoir is emptied, and the Cooperage well also, there is no resource for water for the shipping, but by raising water from the great reservoir by a hand pump.

In this arrangement, the great reservoir may be made use of as a treasury of water for occasional service; and if therefore an intermixture of rain water with the spring water, should be thought of service for the brewing, the surface water from the roofs of the whole buildings, as suggested by commissioner Kirk, may be collected and carried into this reservoir, where it may be kept separately, and used at discretion.

J. SMEATON.

London, 5th Nov. 1779.

I expect that two horses at the new well engine will perform the ordinary service I see going on, but if the full quantity of 200 tons be required to be daily delivered, then to keep the service going during twenty-four hours, will require three sets and one spare horse in case of accidents to the rest, that is, in the whole seven horses.

If thought necessary by way of easing the horses, a wind engine might be raised upon the same building, of sufficient power to perform the whole service, whenever the wind amounts to a fresh breeze.

GENERAL description of the horse engine, proposed to be erected upon the new well, at his majesty's brewery works at Weevil, near Gosport.

PROPORTIONS.

				Ft.	In.	
Mean diameter of the horse track,	-	-	-	30	0	
Diameter of the great wheel in the pitch circle,	-	-	-	19	1	containing 144 } Pitch
wallower,	-	-	-	2	3 $\frac{1}{2}$	17 } 5 In.
fly wheel,	-	-	-	10	0	
Sweep for the crank,	-	-	-	1	6	
Diameter of the working barrel of the pump,	-	-	-	0	6	

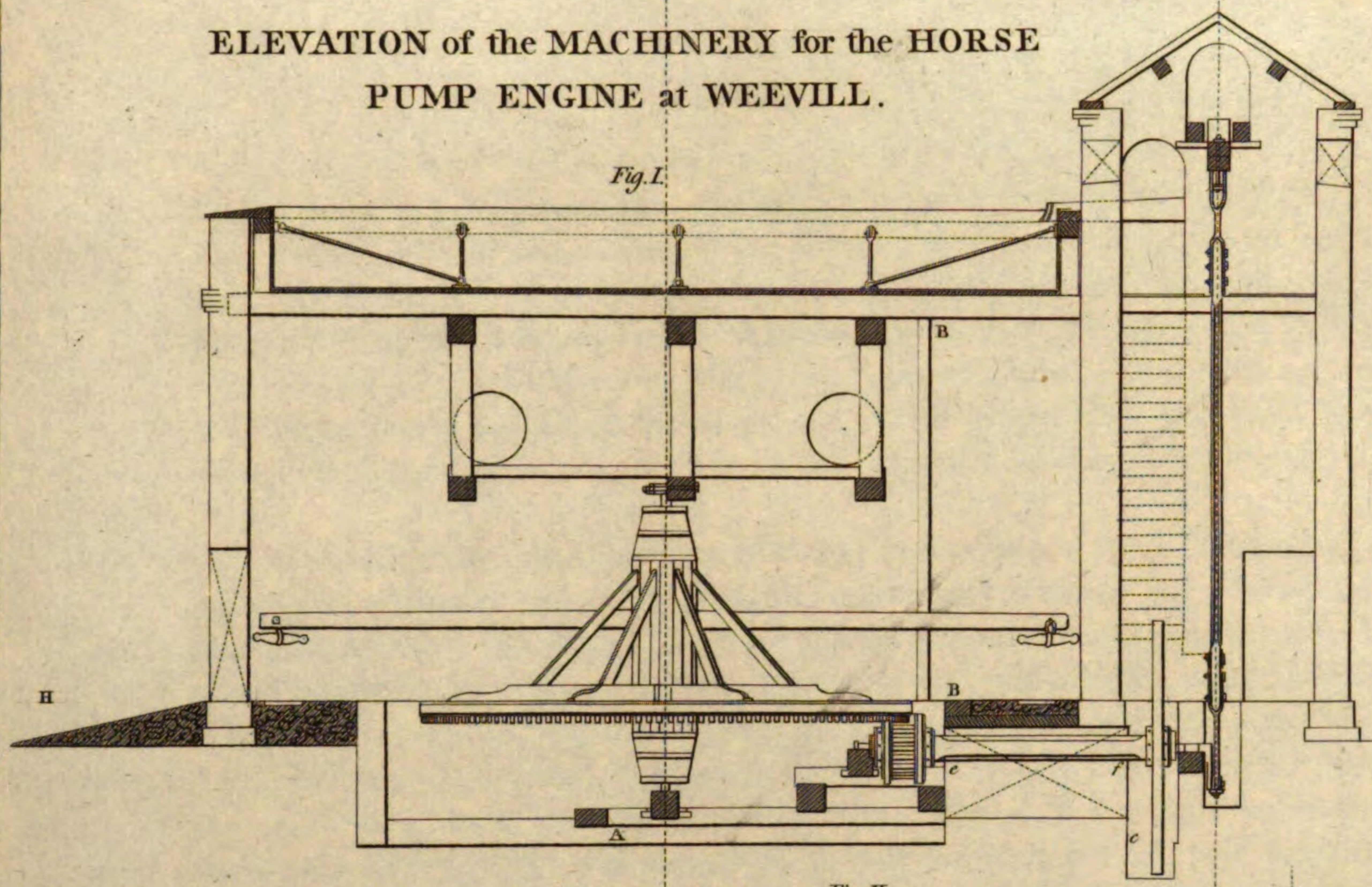
THIS machine, according to the proposition contained in my report to the honourable the commissioners of his majesty's victualling office of the 5th of November last, to which I beg leave to refer, being intended to be made capable of raising water, not only for the supply of the two brewhouses already established there, and to such other brewhouses as may be there erected, but also for the watering of such fleets of his majesty's ships as shall be occasionally assembled at Spithead, to the amount in the whole of 400 tons per twenty-four hours, I have endeavoured to assemble the following properties, that is, strength and durability of all the matter, materials, and fundamental parts, ease of repair of such as are most liable to decay by weather or wear, to have all possible simplicity, so as to be as little subject to be out of order as may be when suddenly wanted upon an exigency, and the whole of such form and construction as to be capable of being adequately repaired, and kept in order by the proper artificers in the country, and lastly, to be capable of raising all the water that can be raised to the same height by the number of horses proposed to be employed; the construction I have designed is set forth in plate .

With this view, to avoid an unnecessary number of moving parts, I have contrived the whole business to be done with a single pump of six inches barrel, and to make a stroke of three feet, and which, from the proportions given to the different parts of the machine, may be expected when the horses are moving at a very moderate working pace, to make from sixteen to eighteen strokes per minute, which rate will deliver 100 barrels per hour, and if worked 24 hours, will amount to 400 tons per day, that is, on supposition that the spring shall so fast supply it, or if not, that an under-ground communication be made with the Cooperage well, or others that shall be sufficient.

A single pump worked by horses would of itself produce a very irregular motion, but this will be equalised in great part by the application of a piece of cast iron, to the inner or crank end of the working beam, which being supposed of or about half the weight

ELEVATION of the MACHINERY for the HORSE PUMP ENGINE at WEEVILL.

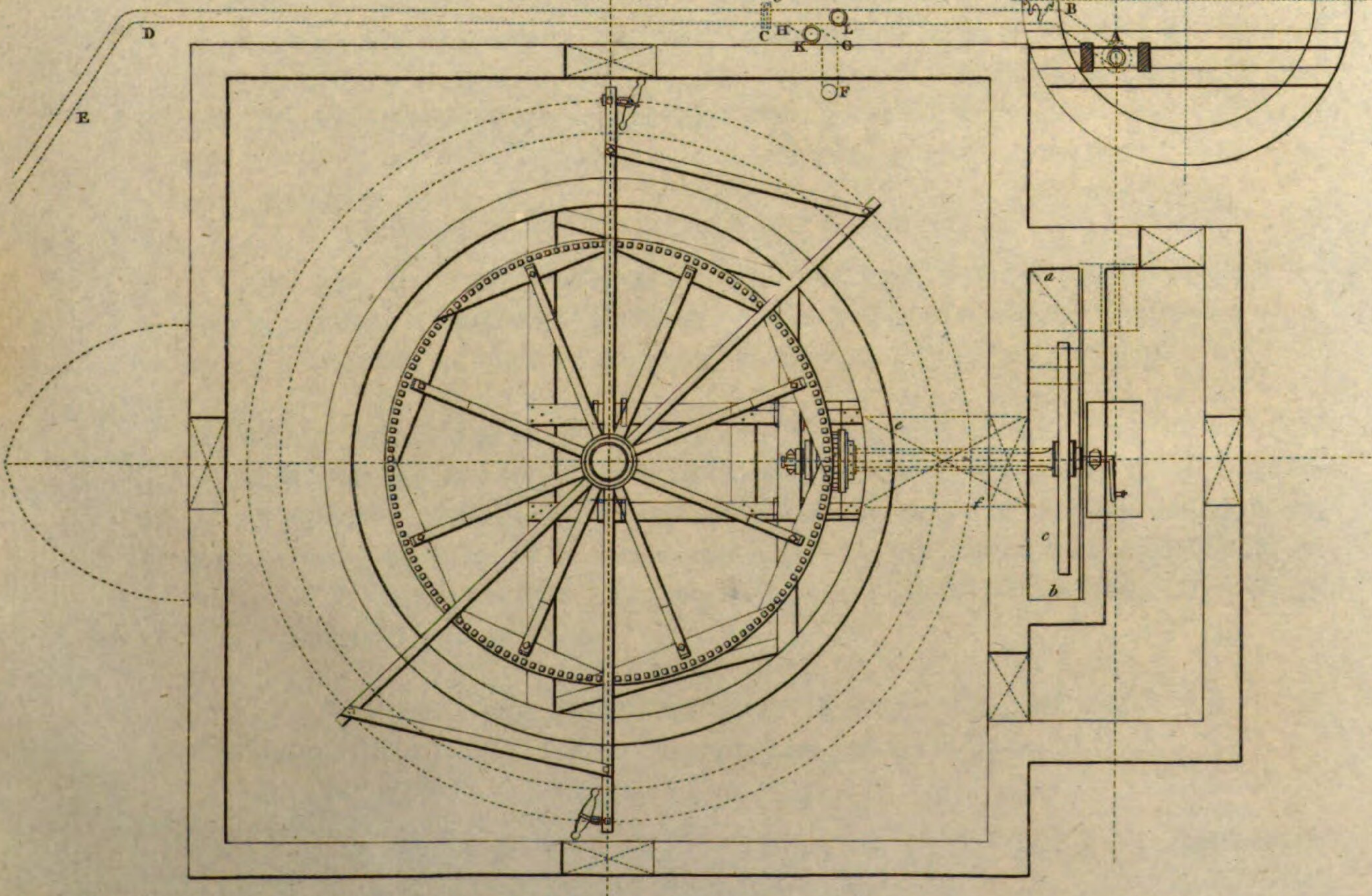
Fig. I.



Scale of Feet
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

GROUND PLAN

Fig. II.



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weight or column of water in the pump, when the crank acts to draw water, it is helped by half its gravity by the weight, and when the spear of the pump is descending to fetch a new stroke the crank is lifting the weight, so that the inequality of the resistance being by this means reduced to half, the remainder will be taken off by a heavy fly of cast iron, applied to the same axis as the crank, which renders the resistance to the horses perfectly equal; this general idea established, the machine is so plain and simple, that I apprehend the whole matter will be perfectly understood by mere inspection of the designs, with such short descriptions as are subjoined hereto.

It is necessary however to observe, that as it cannot be known for a certainty, what quantity of water the spring may produce, its rate of producing water being inferred from the rate of its first filling, and from analogy with the Cooperage well, it doubtless would be satisfactory to know the rate at which it will nearly afford water, before the whole expense is gone into, and in this respect, as a considerable charge seems likely to attend its been emptied with common hand pumps, it cannot be done better than by the engine itself, and which may be ascertained as soon as the machine and pump are fixed, so as to deliver its water at the surface, that is, before the reservoir is made, or pipes laid to convey it; and then there would be no expense incurred more than would be proper for a machine for the new well singly, supposing it no more than equivalent to the Cooperage well in point of produce, save that the building, serving as a shed and cover to the horse track, might have been more slightly founded and built, and also raised to a less height in case it were not intended to carry a reservoir of eighty tons upon the top of it.

I have supposed the reservoir to be lined with lead, this however may be left to choice, as, from calculation of the weight of the lead at 8lbs. to the foot, it does not appear that it will be much more expensive than the rate of back making.

The new pipes laid to convey the water to be six inches diameter, may be either of elm or of iron, for as they will pass chiefly through the waste, and not at all interfere with any present building, if laid with good elm they ought to last full twenty years, and can easily be come at to be renewed; and in case any new building should be wanted to be built across them, iron pipes may then be laid down under the site of such building before it is raised.

It is further to be noted, that all the means of supply that now subsist will remain undisturbed, till it is seen whether the continuance of them be necessary.

Austhorpe, Feb. 19th, 1780.

J. SMEATON.

Explanation

Explanation of plates XI. and XII.

Plate XI. fig. 1. represents the upright section of the house and reservoir, and also of the out-jetty for the crank, working-beam, and stairs, shewing the upright elevation of the machinery.

A, walling for supporting and keeping steady the grand carriages and headstocks.—B B, pipe for conveying the reservoir water to the main.—C, represents a pit, whose bottom must be seven feet below the ground line B H, which is supposed to be level with the surface of the well kirb, and to preserve the necessary width in the bottom, the outside sets off for the length, a b must be in part omitted on the outside of the main well, as shewn fig. 1.—e f in the plan and section is an arched communication between the wheel pit and the pit C.

Fig. 2.—A B C D E, the main pipe of conduct, five inches diameter from the pump to the joint C.—F is the perpendicular pipe from the reservoir to the ground under which it passes through the foundation wall to G, and joins the main from the pump at H.—K L are two stop cocks.—K is the reservoir stop cock, which, being shut, retains the water in the reservoir, while L being open can send it as the engine draws it to the quay reservoir, or even to the liquor backs of the brewhouse.—L is the pump stop cock, which being shut, will oblige the water to ascend to the reservoir in preference to all other places.

Plate XII. fig. 1. is a section through the middle of the out-jetty and elevation of the building, working-beam, and pump, also a front view of the pump and corner of the building; in these figures the dotted squares a b and c d, denote two pieces of oak to be walled flush into the respective faces of the building, of about $3\frac{1}{2}$ or four feet long, each containing a mortise for a hook tennant to fix the ends of the cross pieces, for steadying the pump, frame, and stage.—e f shew the pit for the crank.—g h shew the headstocks or carriage for the crank neck gudgeon.—W, a cast-iron weight to balance part of the weight of the column of water in the pump, to be eighteen inches long, ten inches wide, and nine inches high.

Fig. 2. is the design for the pump, being a front section of the brass barrel and clack seat piece of cast iron.—A B, the brass barrel.—C C, the leaden pump bore screwed down with a flanch thereupon, to be five-eighths thick at the length next the barrel, and each

WEEVILL ENGINE.

End View of Weevill Engine.

Fig. 1.

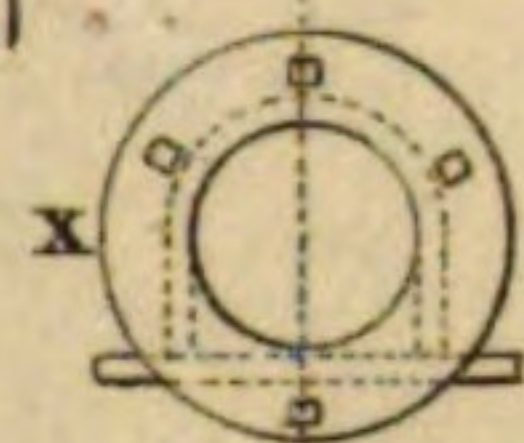
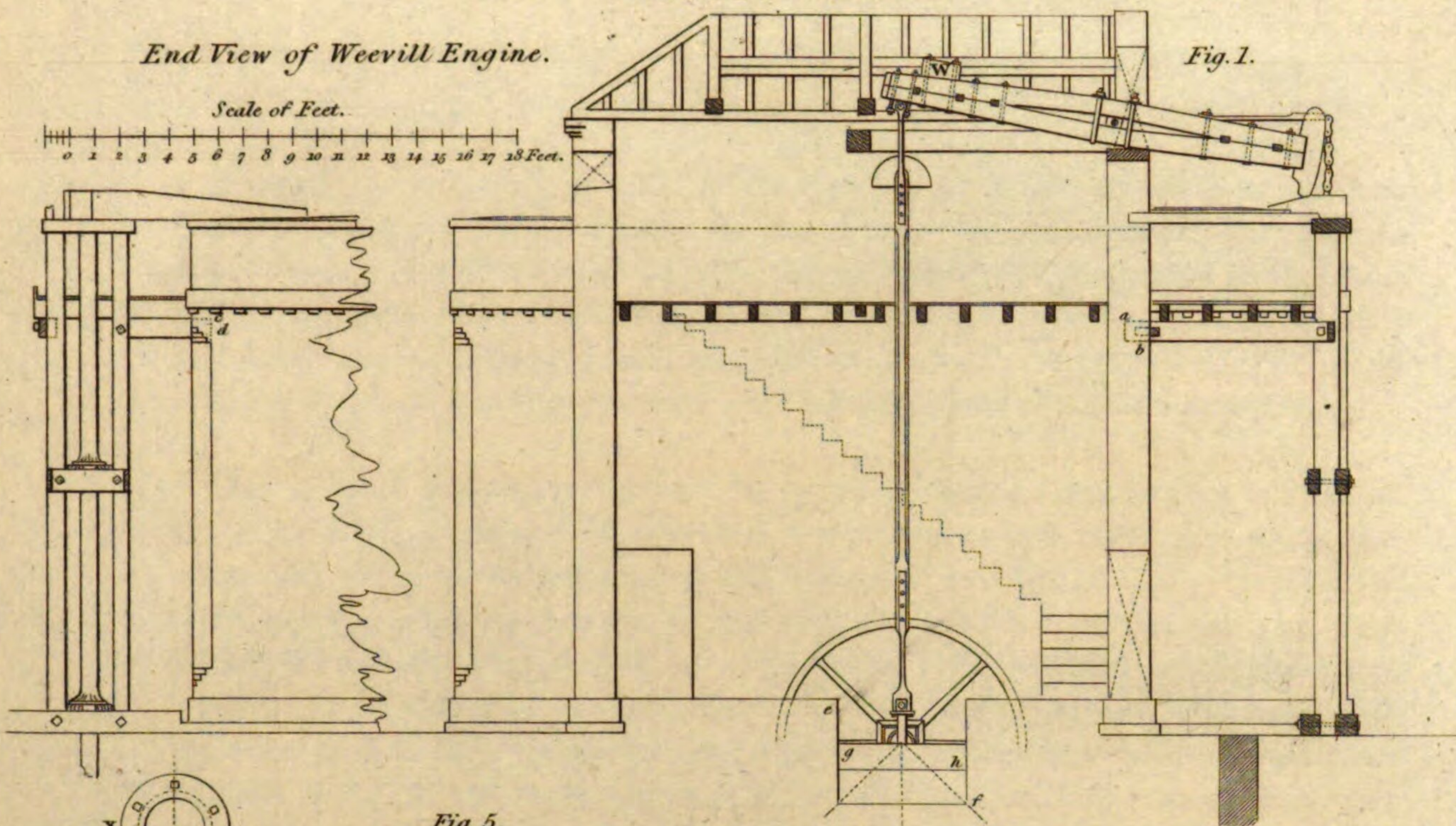


Fig. 2.

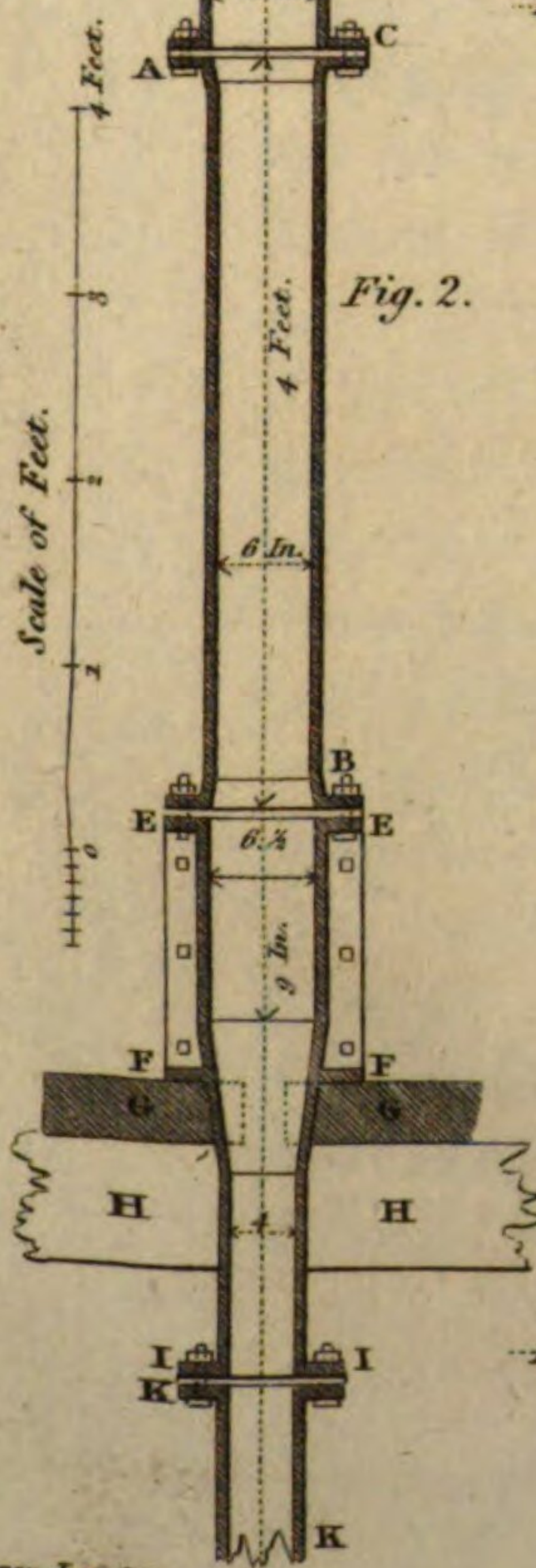
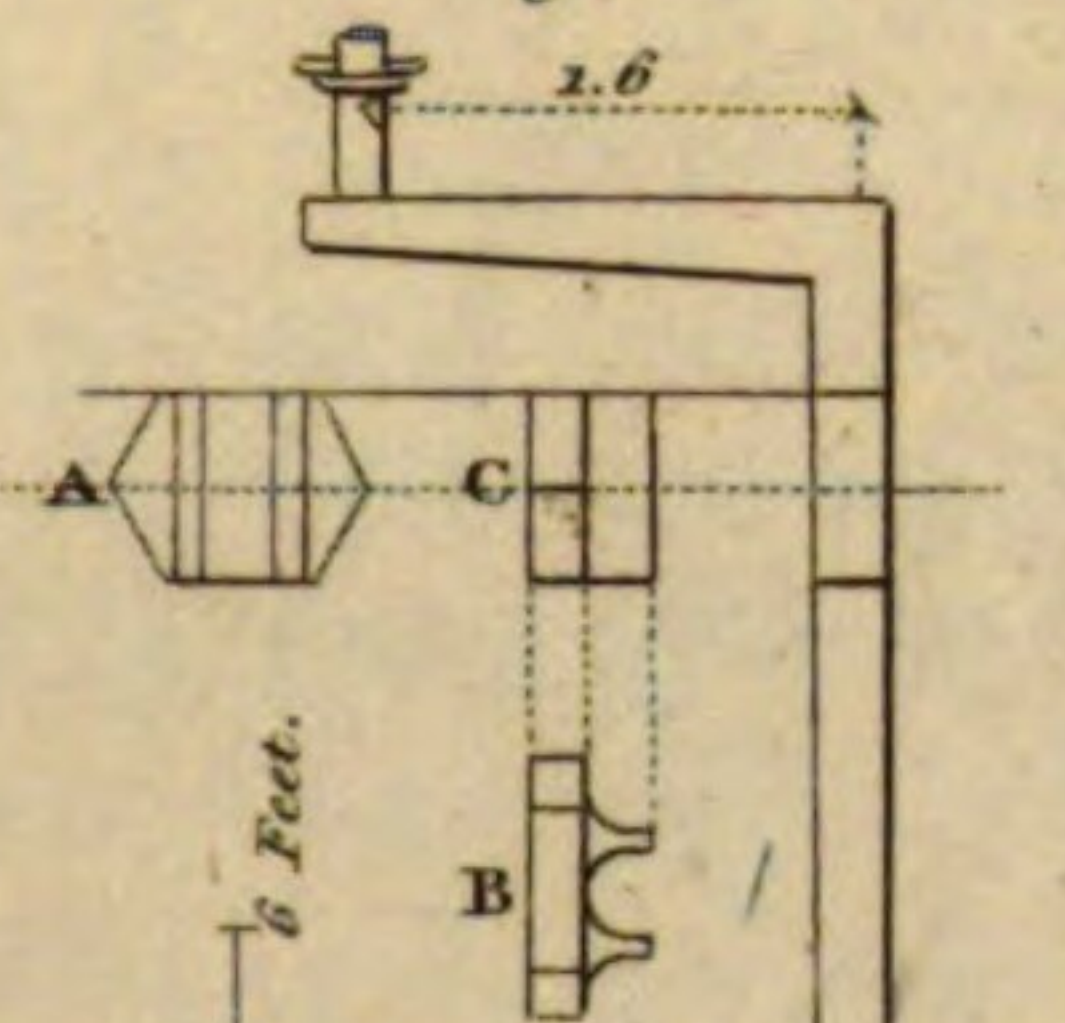


Fig. 5.



Scale of Feet.

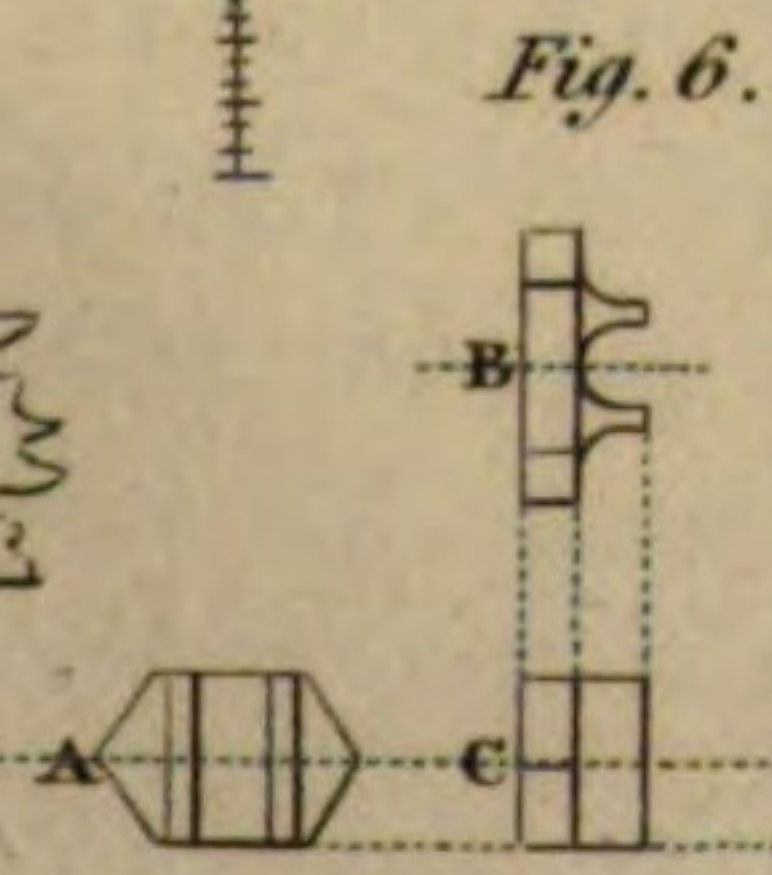


Fig. 4.

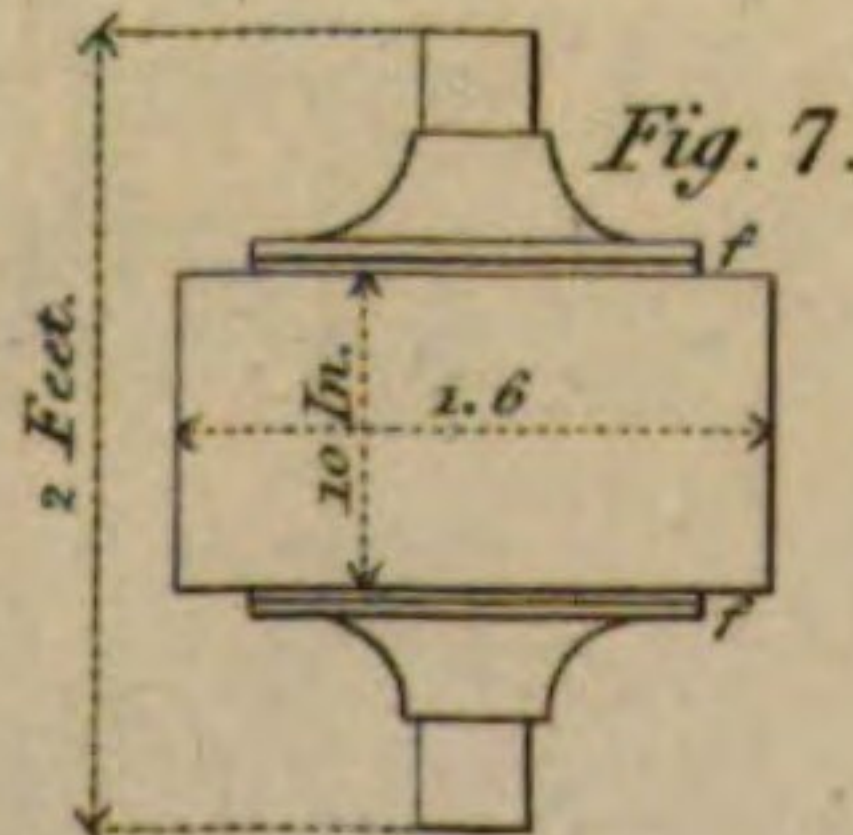


Fig. 7.

Fig. 3.

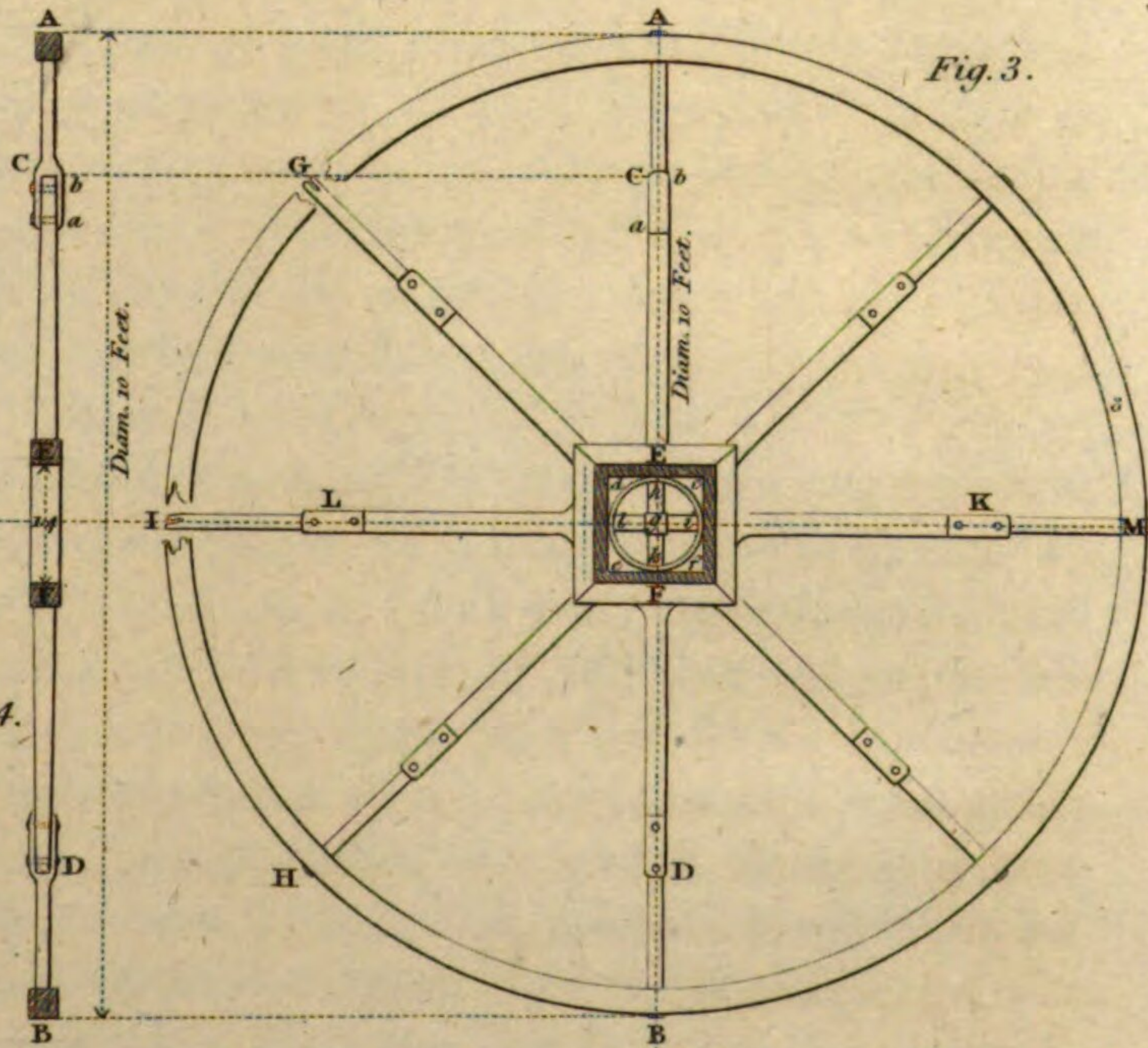
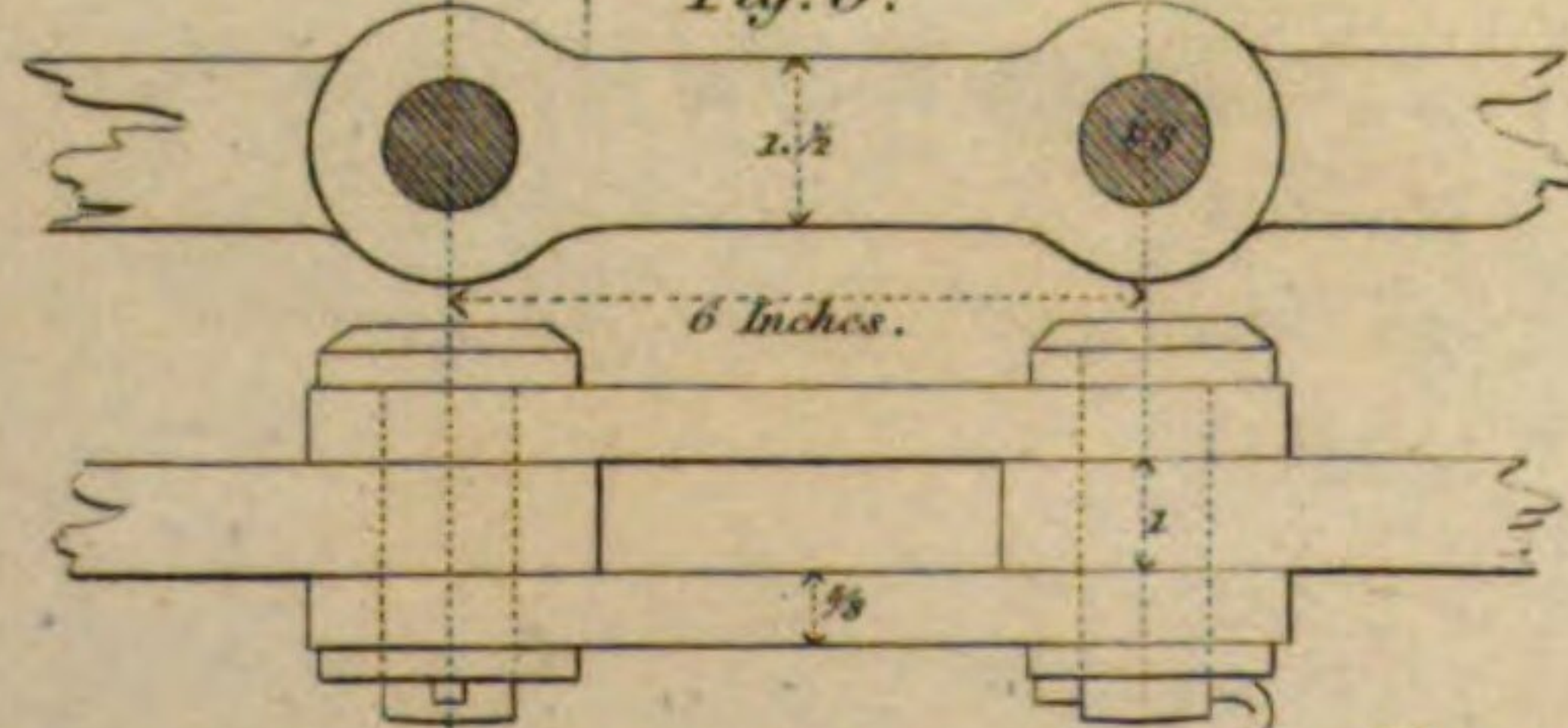


Fig. 8.



J. Farey Jun. del.

J. Smeaton 1780.
W. Lowry sculp.

each length gradually less, so as to be three-eighths thick at the top.—E F is the clack door piece, whereof E E is the upper flanch, whereon the brass barrel is screwed, and F F is the lower flanch, which rests upon the cross planks G G, supported on the beams H H, supposed double. The clack seat-piece terminates in the flanch I I, to which is screwed the leaden suction pipe K K, the bottom of which must be pierced with sixteen blast holes, of one inch diameter.—X is the plan of the top of the clack seat-piece.

Fig. 3. shews the construction of the fly wheel, whose circumference is intended to be three inches square in cast iron, with eight round holes for fixing the arms, which arms are in part to be of cast iron, but joined to the ring by pieces of wrought iron, which will prevent all difficulty in the casting, and at the same time furnish the means to bring it to its true centre; fig. 4. is a section of the fly wheel, which it is necessary to consider along with the other, the same letters denoting the same parts in each. A B, the ring of the fly wheel, ten feet diameter. C D, two opposite arms of cast iron, being eight in number, and all connected in one piece by the square E F, whose internal opening is fourteen inches; the end of each arm is to be perforated with a couple of holes of about three-eighths of an inch diameter, as at a b, by which the wrought pieces a b, C A, are rivetted and firmly fixed upon the cast iron ones, so as to make them out to a proper diameter, and being brought to a centre, they are fixed in the circumference of the ring (the ends being split to receive a wedge as is shewn at G & I) exactly like a trenail, which, being fastened, the surplus is chiseled off, and the circumference left even.

The only circumspection that is necessary in fixing the arms, will be (after they are all respectively fitted and set fair, the wrought to the cast iron stumps) to get the two opposite ones, as suppose, A C and B D into place, (the whole lying horizontally) and rivetted, but not wedged, which is not to be done till the last, then one of the side ones, as suppose I L is to be got in and rivetted, which done, that for the opposite one at K M, the double part is to be made hot, so that when offered to the arm, a few gentle blows of a hammer, supported by an opposite sledge, will bring it to set quite true to the cast iron, when this may also be rivetted; and in like manner the other four are to be got in and rivetted one by one, heating the double parts to make them set true, if found necessary; lastly, the wedges are to be driven, and the whole, by the means above observed, having no false bearings, the strength of the whole will be united, and the wheel may be moved at pleasure.

When

When the fly wheel is hung, the square c d, e f, of twelve inches, is supposed to be the end of the wooden axis (upon which also the wallower is to be fixed) the intermediate space being left for wood wedges to be hung, and brought into round and flat like a wooden wheel; g, is supposed a section of the iron spindle, and h i k r are staple cramps driven in between the spindle and the hoop to prevent its getting loose, the same being also supposed at the other end where the wallower is hung.

Fig. 5. shews the crank gudgeon; fig. 6. shews the wallower gudgeon, with their bearing brasses. The neck of the crank gudgeon is not proposed to be steeled, but made of good tough iron well hammered, and smoothly turned, and left of the full size of $2\frac{5}{8}$ inches diameter, so that being seven inches in the length of the bearing, the wear will be very inconsiderable; the wallower gudgeon will be easily understood by the figure, the boss or head of the end being intended to counteract the tendency of the wheel, to drive the wallower from it.

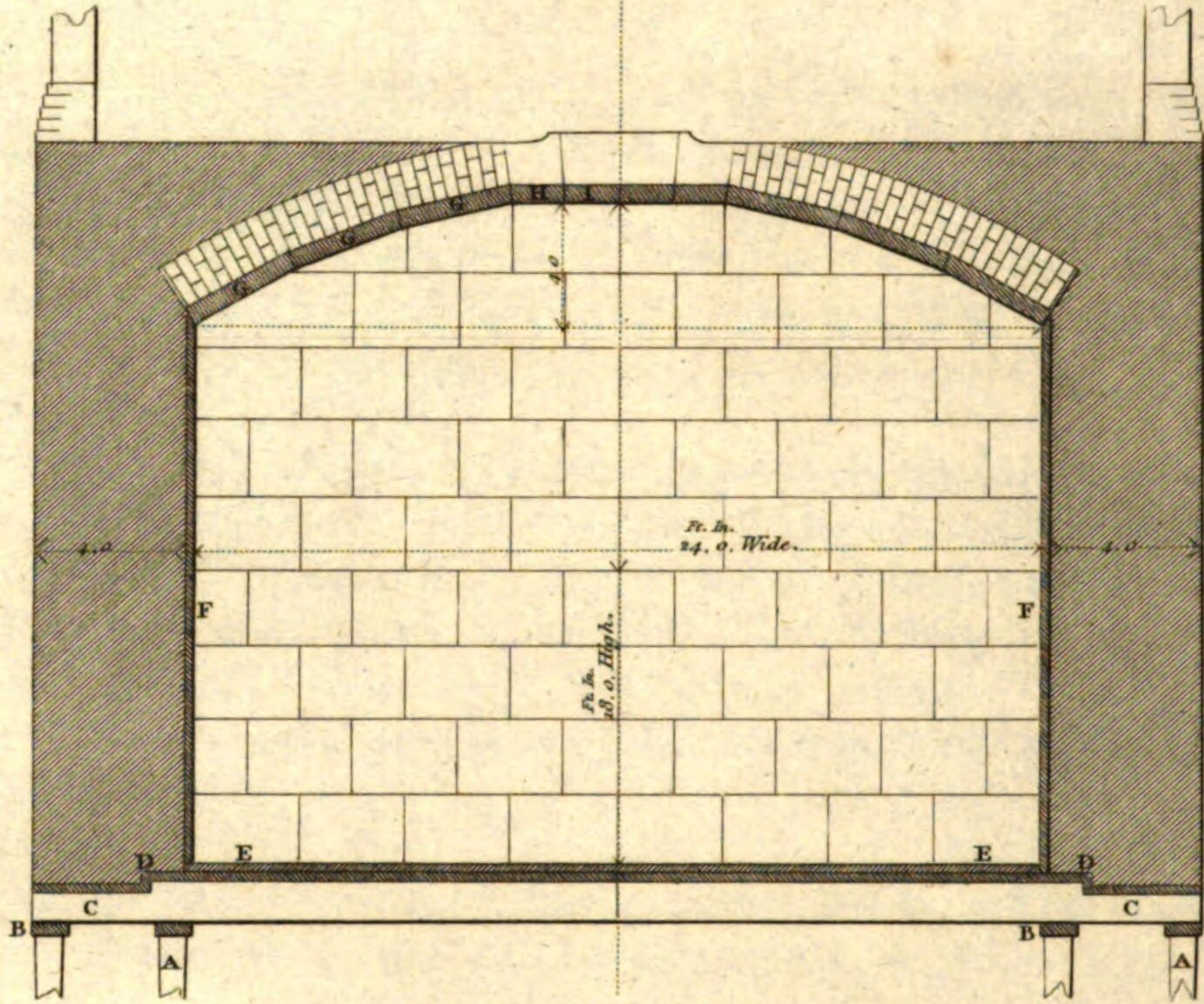
A A, are the plans of the respective bearing brasses; B B are the uprights thereof seen endways of the gudgeon, and C C are the uprights as seen crossway of the gudgeon.

N. B. The two gudgeons fig. 5 and 6, according to the designs, are supposed to be of one intire piece or bar, tapering gradually from $2\frac{5}{8}$ at the crank end to $2\frac{3}{8}$ square at the wallower end, put through a wooden axis bored like a pipe, and opened at each end to a square, to admit of wedges, and afterwards to be secured with staple cramps, as described for the fly wheel but as the smith may not have a convenience to turn it in one piece on account of the length, being fourteen feet three inches in the spindle part, it may be made in two pieces, each properly centered and turned, and then shut together in the middle, and brought to a straight line; but if this should happen to be attended with difficulty, they may be made separately and laid into the wooden shott, with a screwed T at the tails, as shewn in the designs, and secured with staple cramps as already specified.

Fig. 7, is the plan of the cast iron gudgeon for the working beam, of the thickness of three inches, except that f f represent two fillets on the upper and under side, to keep the gudgeon immoveable, between the two beams, of which the working beam is proposed to be composed, and which is firmly clipped in by the screw stumps shewn in Fig. 1, the gudgeons, if not turned, must be smoothed with a file. Fig. 8. shews

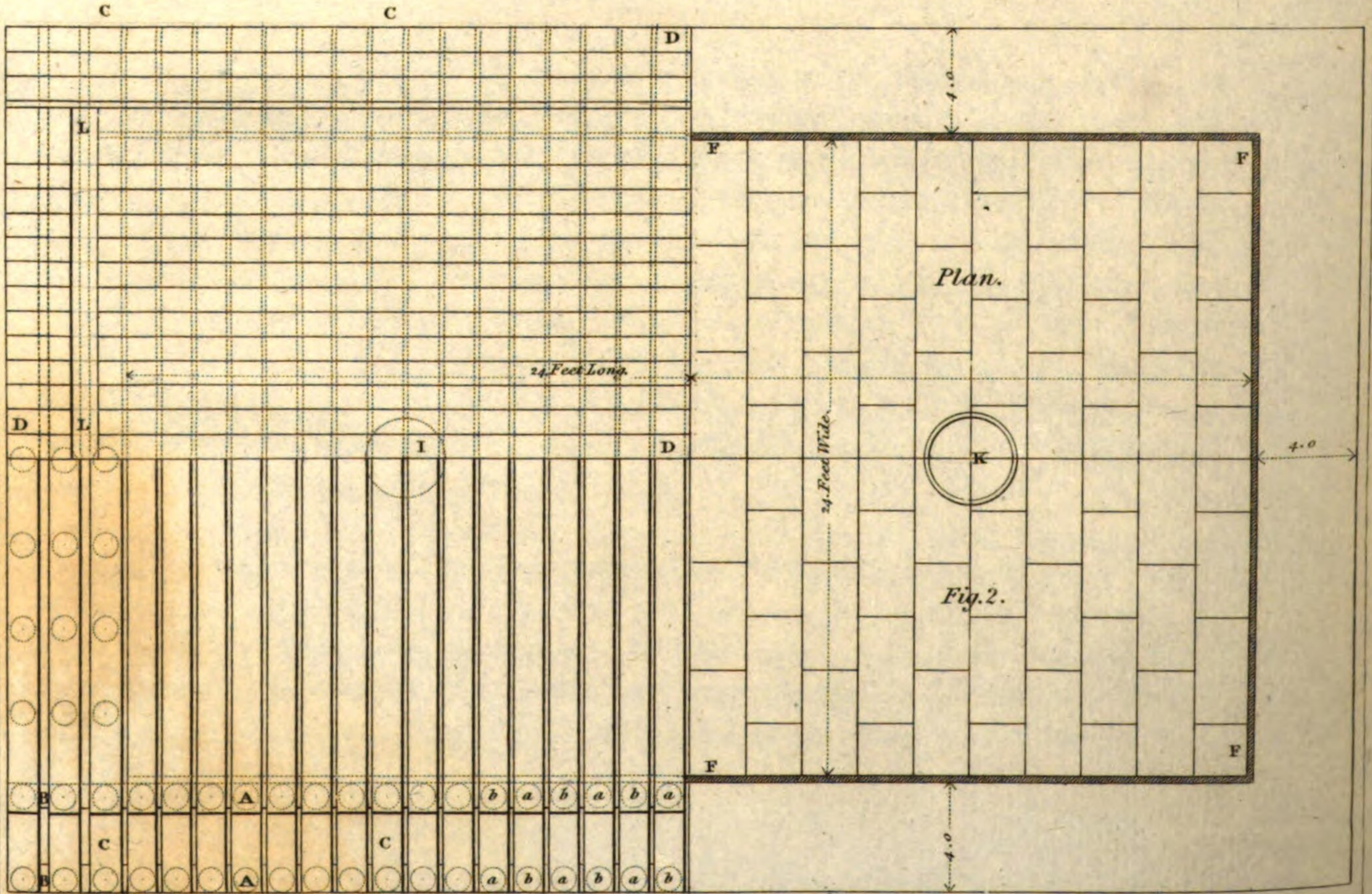
DESIGN FOR A STONE BEER VAULT FOR WEEVILL BREWERY.

Scale of Feet & Inches.
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 Feet.



End
Section.

Fig. 1.



Plan.

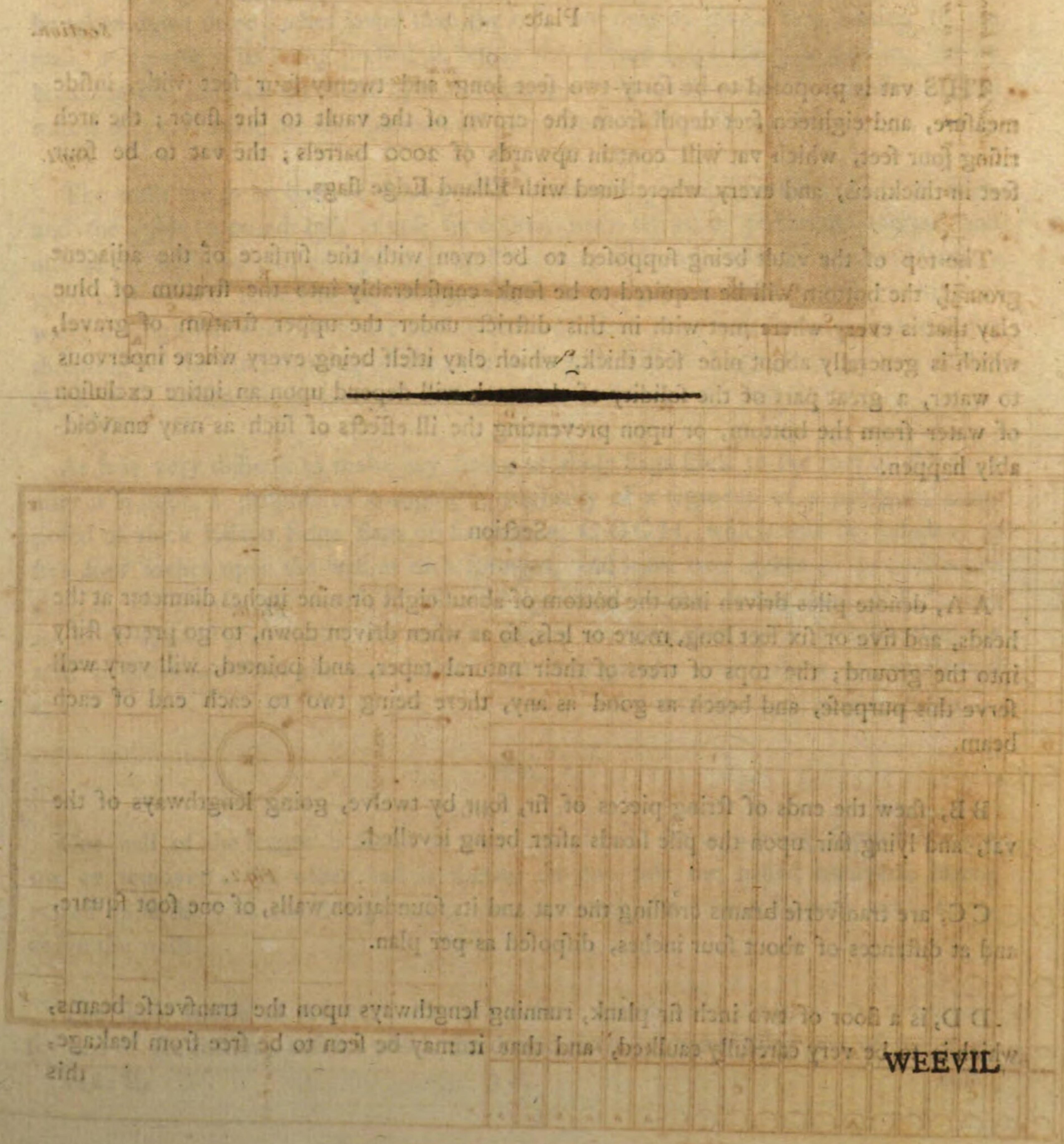
Fig. 2.

J. Farcy Jun. del.

J. Smeaton & S.
W. Lowry sculp.

shews the design for the links of the pump chain, on a larger scale, which will be sufficiently explained by inspection.

N. B. By way of giving a durability to the wallower, I would recommend the rounds to be of cast iron, turned or well smoothed with a grindstone, by this means the part most subject to wear will last many years, and always be in order for work.



WEEVIL BREWHOUSE.

DESCRIPTION of the design for a stone beer vat for his majesty's brewhouse at Weevil.

Plate .

THIS vat is proposed to be forty-two feet long and twenty-four feet wide, inside measure, and eighteen feet depth from the crown of the vault to the floor; the arch rising four feet, which vat will contain upwards of 2000 barrels; the vat to be four feet in thickness, and every where lined with Elland Edge flags.

The top of the vault being supposed to be even with the surface of the adjacent ground, the bottom will be required to be sunk considerably into the stratum of blue clay that is every where met with in this district under the upper stratum of gravel, which is generally about nine feet thick, which clay itself being every where impervious to water, a great part of the solidity of the work will depend upon an entire exclusion of water from the bottom, or upon preventing the ill effects of such as may unavoidably happen.

Section

A A, denote piles driven into the bottom of about eight or nine inches diameter at the heads, and five or six feet long, more or less, so as when driven down, to go pretty stiffly into the ground; the tops of trees of their natural taper, and pointed, will very well serve this purpose, and beech as good as any, there being two to each end of each beam.

B B, shew the ends of string pieces of fir, four by twelve, going lengthways of the vat, and lying fair upon the pile heads after being levelled.

C C, are transverse beams crossing the vat and its foundation walls, of one foot square, and at distances of about four inches, disposed as per plan.

D D, is a floor of two inch fir plank, running lengthways upon the transverse beams, which is to be very carefully caulked, and that it may be seen to be free from leakage,
this

this floor, where not necessarily covered by the walls, is to be left uncovered till the last, and where defective, amended, after which it is to be covered with

EE, a paving of large four inch Elland Edge flags, well jointed and bedded in terras or pozzelana mortar.

The ends of the transverse beams, at one foot from the inner face of the walls, are to be taken down three inches lower than the rest, not only to give a firm footing to the wall, and prevent its being pressed in before the Elland Edge floor is put in, but by breaking the joint of the walls upon the floor, will be likely to be the most effectual means of preventing the transpiration of water from without through that joint.

The walls are to be built of strong well burnt brick, carefully walled on both sides, and the inside grouted full, course by course, with terras or pozzelana mortar, and also as the walls are carried up, they must be very well and carefully plaistered with a good coat of the same mortar, to prevent in every possible degree the reverting of water through the walls from the outside inward, when the vat is empty, and thereby throwing off the inward lining of the side walls with Elland Edge flags of two inches thick FF, which are to be applied after the outwalls are built and settled.

As it is very difficult to make any lining of those flags stick to the roof of the vault after it is built, I propose to compose it originally of a segment of a polygon, composed of thick Elland Edge flags of six inches, GGGH, which will be sufficient to step four inches upon the wall at each springer, and leave two inches of projection to close in, and fix the top course of Elland Edge flags of two inches thick, FF, which are to be applied after built; the middle pieces are supposed to be broader than the rest, in order to admit the man-holes to go through the entire stone as represented at I.

Plan.

One half of the length is shewn as when completed, the arch being supposed unput on, or removed; the other half is shewn, on one side the naked transverse beams rested upon the piles and string pieces, the other with the timber flooring ready to receive the walls.

The same letters of reference denote the same members in the plan, as before described of the section, besides which the dotted circle I, representing one of the man-

holes, K being in place of the other, shews a kind of pan of cast iron of one inch thick, and three inches deep, its upper border to be even with the stone floor, and composing a part thereof; its use will be that in emptying the vat by a pump, it will serve as a pump to drain the whole floor; underneath the other man-hole may be a similar one, if thought necessary, and I would recommend two openings in preference to one, because the vault can be more easily ventilated, and either or both can be shut, if occasion require, by laying a border of clay round them, and a flat stone upon them.

K L represents a riband let one inch into the planking, and projecting upwards three inches, to serve the same purpose at the ends as the letting down of the beams for the sides,

Precautions in founding the floors.

As a principal concern will be to found them clear of water, the clay must be uncovered to a sufficient breadth to sink the rest of the foundations therein, leaving a border by which the water issuing from the gravel may be collected in one place, and there pumped out continually, without letting it run down into the cavity in the clay, which it is expected will afford no water, and it may be considered whether it may not be less expence to form a drain for it into the new well, the water being continually kept down there for the necessary purposes of brewing, &c. than keep a pump going continually for the purposes abovementioned.

When the piles are driven, and the string pieces established, the clay must be carefully beaten under them, and up to them, and to prevent them from rising, they should be trenailed at every other pile, as a, a, a, a, a, &c. and as the transverse beams are brought on, they must likewise have the clay beaten under them, and to prevent their rising, should be trenailed to every other pile at b b b. b b b, &c. so that every beam will have a trenail at each end, and before the floor is laid, the interstices between the beams should be beaten up with clay, endeavouring to make all completely full if possible, without using so much force as to draw the trenails. Lastly, in laying down the planking, they should each be progressively under beaten with clay, so that all may be full, and as much as possible exclude the admission of water from showers or otherwise; and round the whole border of the timber-work, the clay being beaten up to a level with the floor, the brick-work may then be established thereon.

Precautions

Precautions in raising the brick-work.

Care must be taken after raising a competent number of courses, and performing the terras plaistering outside as before mentioned, to pick up and cleanse all the scraps of brick, lime, &c. from the clay bottom, and carefully fill in behind the wall with clay in its natural or middling state of stiffness, so as to make all so close together, as to exclude the water, and that rather by treading than ramming, for by violent ramming in of more stubborn matter, the wall might be bilged if twice as thick as prescribed; this is to be done as high as the natural stratum of clay reaches; after which a coat of clay of three or four inches thick behind the terras plaister will be sufficient, with common filling, ramming the materials pretty tight behind the springing of the arch, after the arch is turned.

When the arch is completed, the Elland Edge lining of the side walls may be proceeded with, to be flushed upon the back, and in part jointed with terras mortar, to be finished in the face with cement of Mr. Whitbread's composition, and lastly the floor, taking care to stop all transpirations in the caulking or planks, if any appear.

The best lime for the purpose will be had from Watchet in Somersetshire, upon the Bristol channel.

The best composition two parts lime in flour, one part of pozzelana or terras, and one part clean sharp sand, well beaten to a tough paste, and the grout to be made (not from the raw materials, but) from the beaten mortar diluted with water to a proper consistence when well stirred.

J. SMEATON.

Austhorpe, 26th August, 1780.

CHIMNEY WINDMILL.

EXPLANATION of the designs for Chimney Windmill.

PLATE XIV. exhibits a vertical section of the whole mill. Plate XV. figs. 1 and 2 are designs for the whips, fig. 4, is a plan of the upper kirb, and moveable part of the kirb, and fig. 3, represents part of the cap seen from behind.

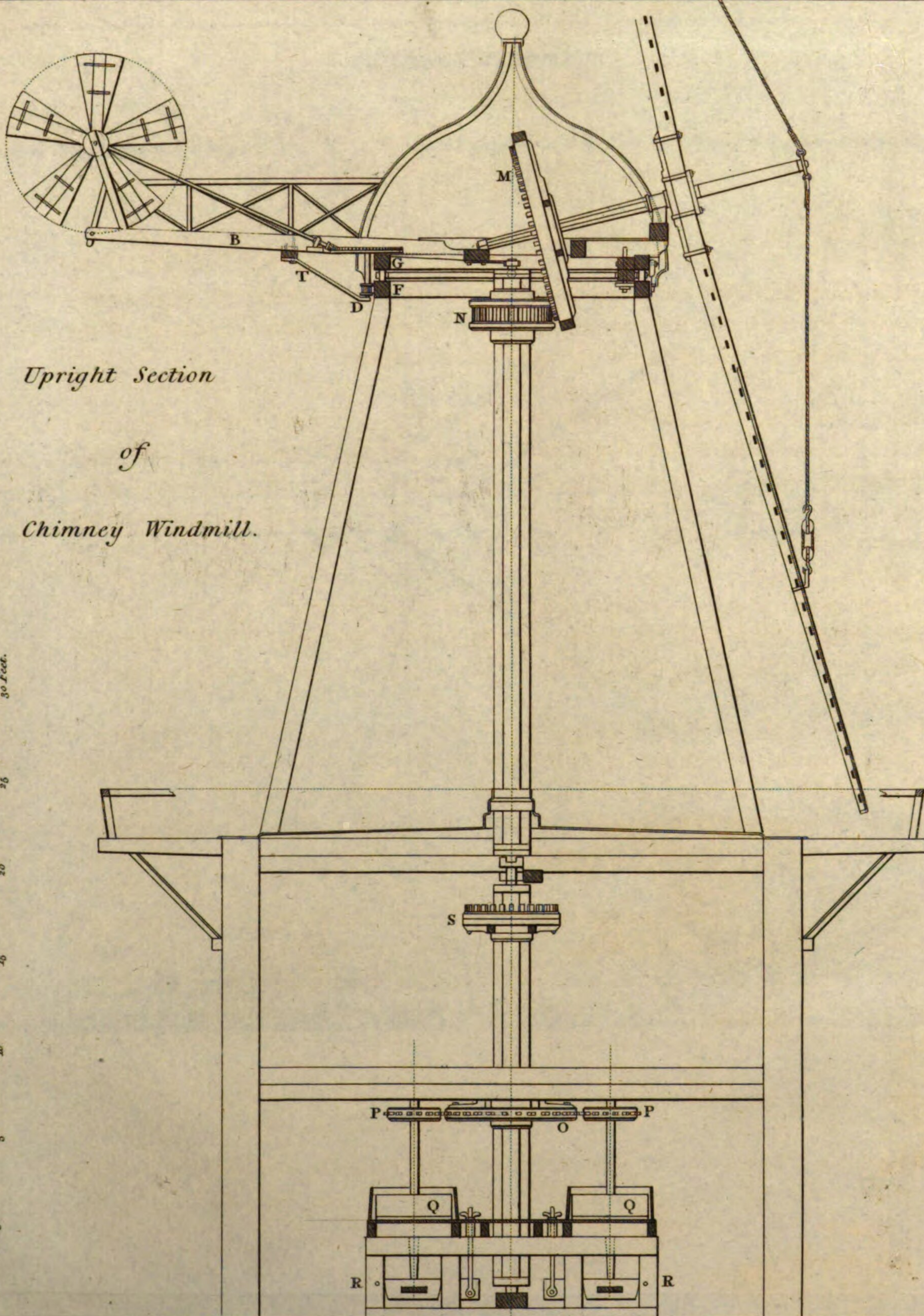
A B, plate XV. fig. 1, is the master whip, reaching eight inches beyond the centre. a b c d shew the master tenant, shouldered two inches on the under side, and two inches on the upper, which will leave it five inches in thickness. C D and E F, are two whips that are mortised on to the master tenant, and butt upon it, in the line a b, and also mitre with each other according to the line B e. G H and I K are two whips that are brought on after the three former are in place; they mitre into the angles of the former upon the lines f a g, h b k; their tenants are shaped according to the line f l m g, as relative to the whip G H, and the other in a similar manner. These tenants are shouldered two inches upon the upper face, and four inches upon the lower face, and are three inches thick.

N. B. That part of the master tenant that is mortised away for the tenants of the whips G H, I K must be continued to the end of the master tenant; that is, the space a m n must be continued out to d o, by which means the master whip, as well as any of the rest, can be drawn out singly, to be repaired in case of accident.

Fig. 2. shews the manner in which the whips are to be stirruped down upon the horns, being a section seen sideways, wherein A B is the master whip, C D the same whip, as that in the plan fig. 1. marked with the same letters; f h c d, is the master tenant, and i k the place of the tenant of the whip I K, but the mortise to be cut out of the master tenant to the end at d.

The proportions of the wheel work are as follows:

The sails are thirty-four feet nine inches long from the centre, and six feet wide across the face of each sail; the brake wheel M, plate XIV. has seventy-two cogs at five inches pitch; the wallower N, which it turns, has thirty-one, at the same pitch; the main spur wheel O, seventy-two cogs, at four inches pitch; the nuts or lanterns P P,



*Upright Section
of
Chimney Windmill.*

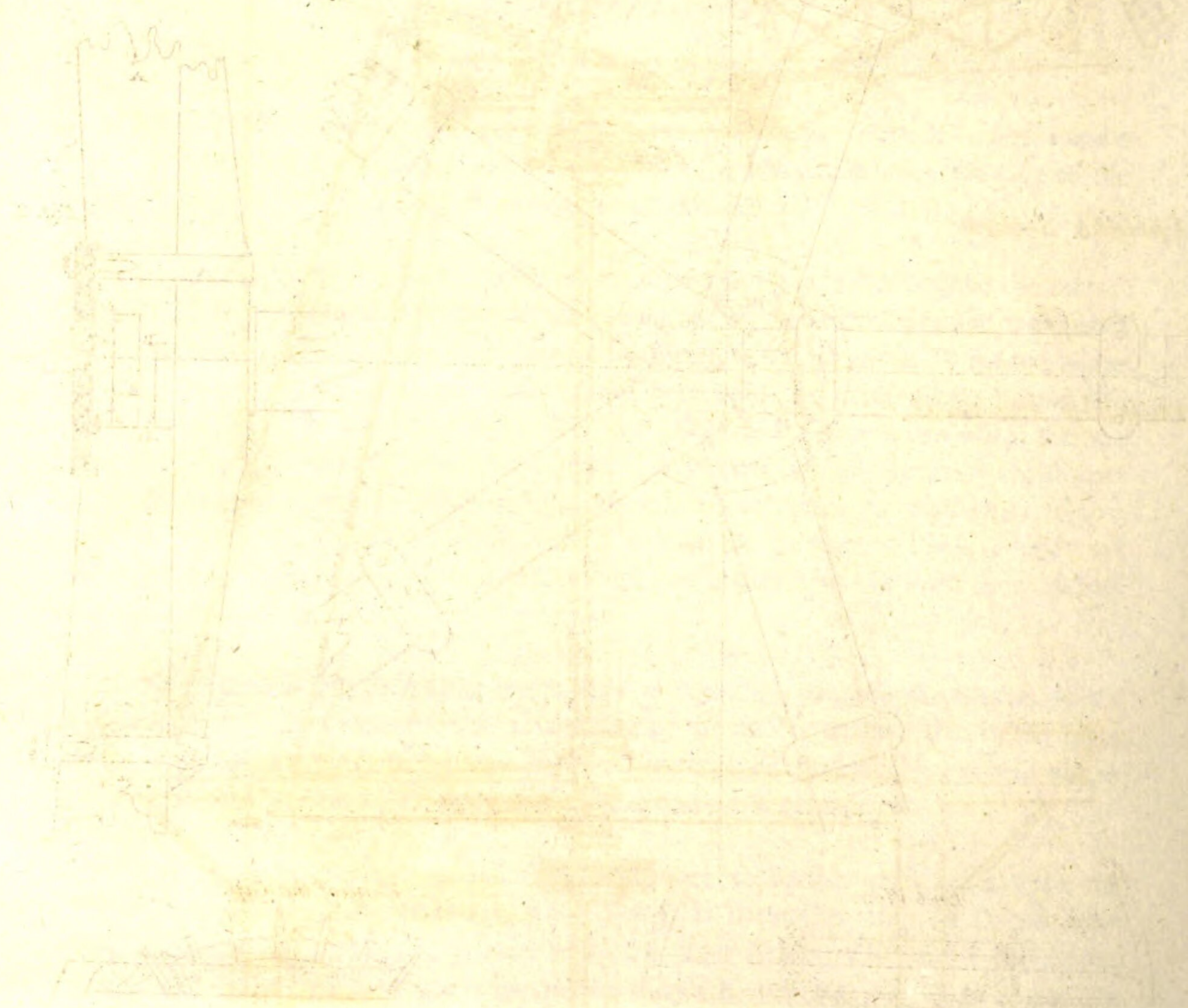
Scale of Feet.
30
25
20
15
10
5
0

J. Farey Jun. del.

J. Smeaton 1782.

W. Lowry sculp.

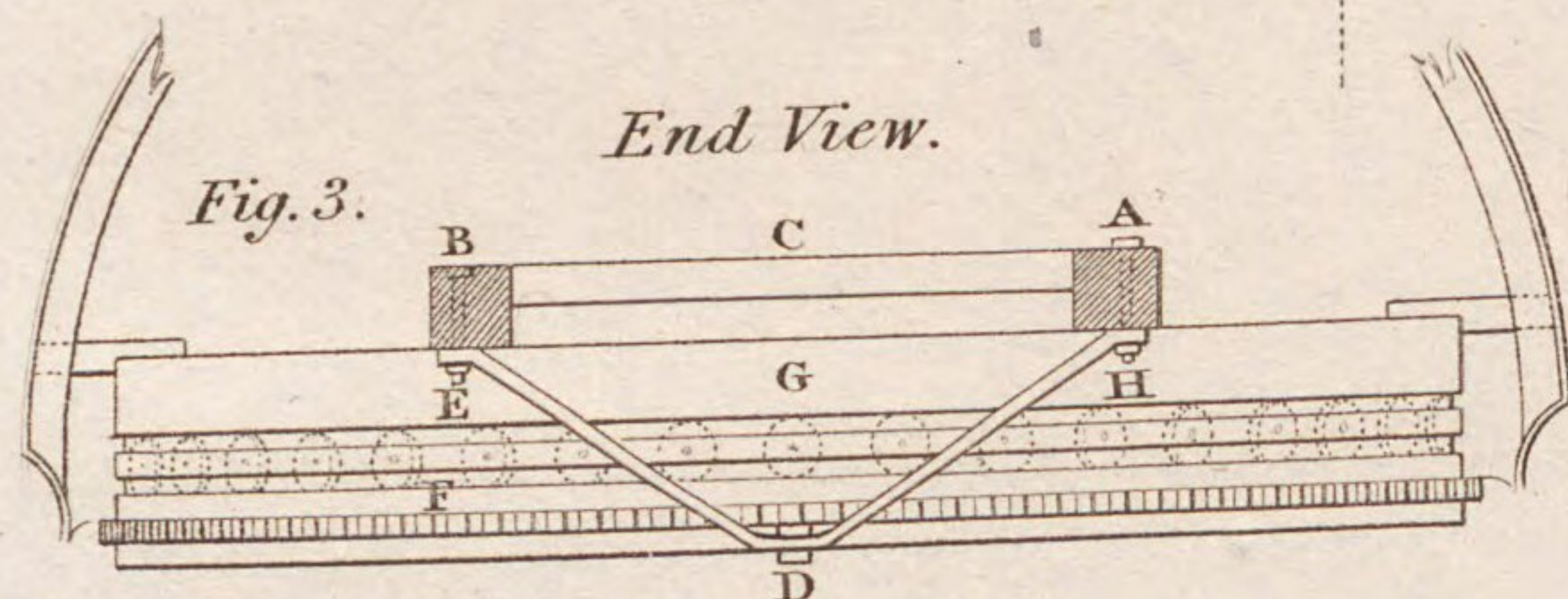
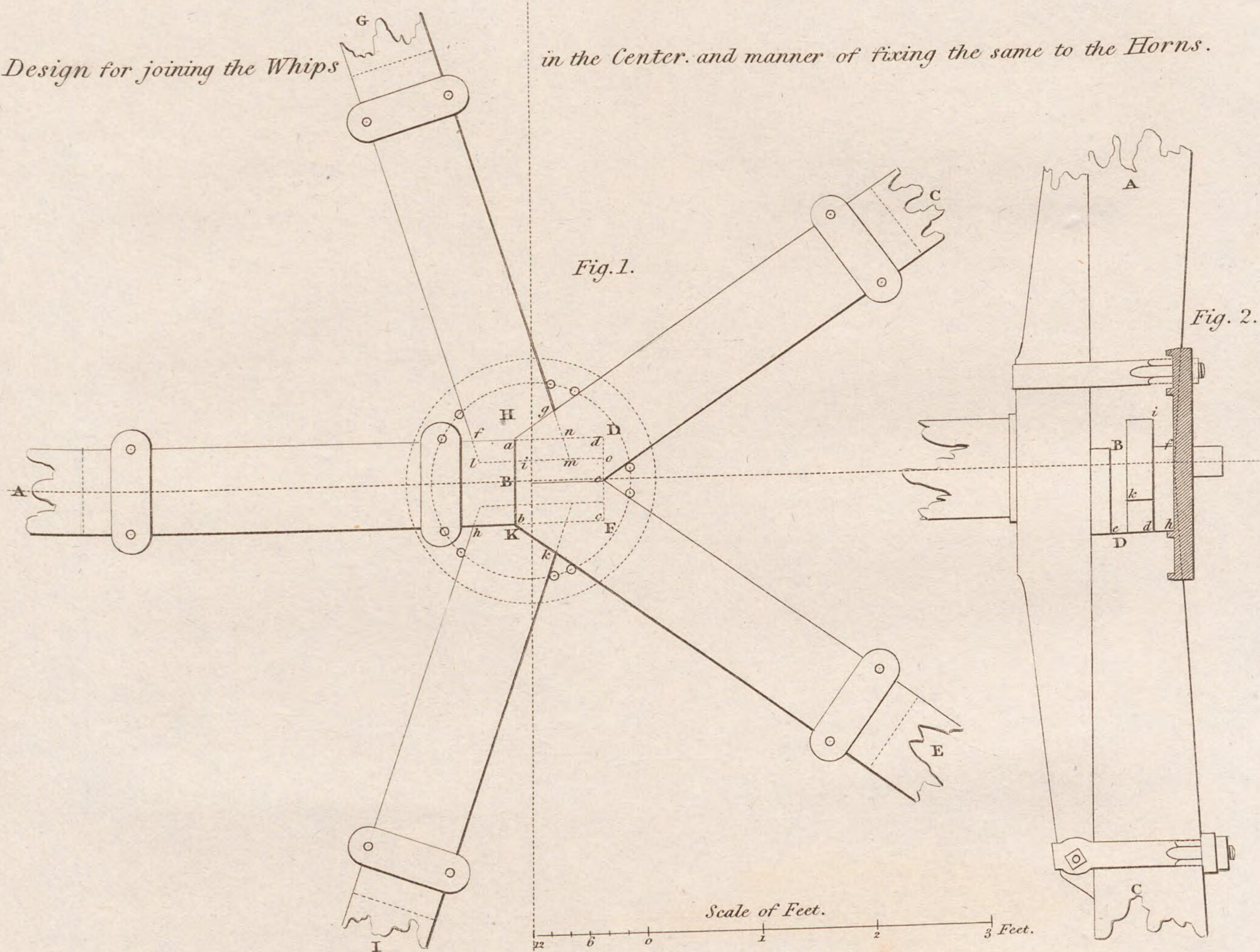
THE CHARTERED BANK OF ENGLAND



CHIMNEY WINDMILL.

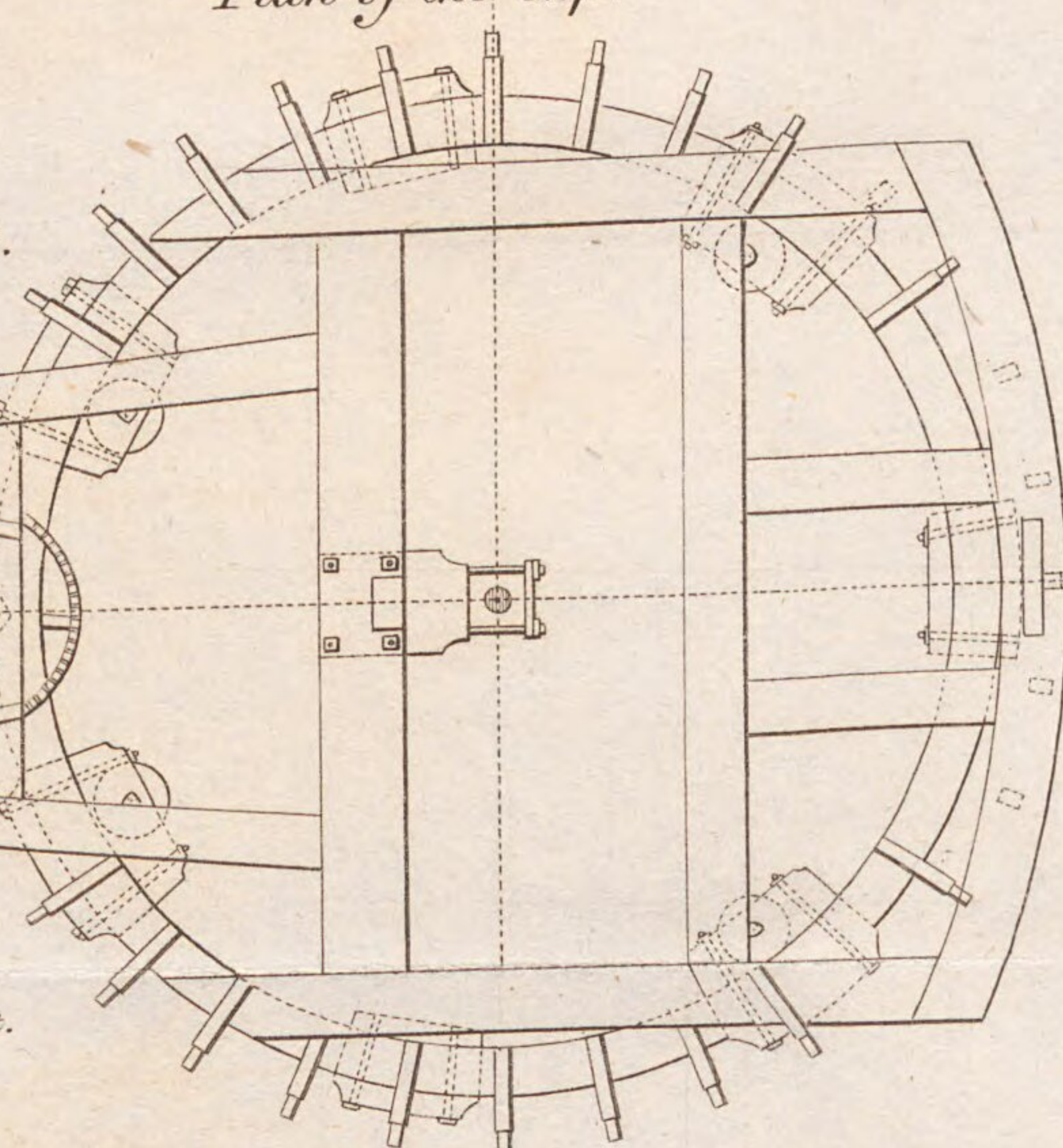
Design for joining the Whips

in the Center. and manner of fixing the same to the Horns.



Plan of the Cap.

Fig. 4.



P P, for the two pair of four feet blue stones Q Q, contain twenty-six cogs, at four inches; the nuts or lanterns, for the two pair of five feet stones, twenty-eight cogs, at four inches; these last are not shewn in the design, being behind the others, with which they form a square, upon the Hirst R R, one pair of stones being situated at each angle. The swimming wheel S, which is for driving the small geer, has fifty-six cogs, at $3\frac{1}{4}$ pitch.

In fig. 3, of plate XV. which is an upright of the hind part of the cap A B, are sections of two tail trees, which support the tail vanes; C D, the perpendicular line, being the centre line of the upright spindle; G, part of the upper kirb; F, part of the lower ditto; H D E, the two iron arms or braces, which, at D, support the brass box for the lower gudgeon of the pinion, which turns the cap round, the box is received in a broader and stronger part of the iron brace; the box and gudgeon, and consequently the lantern are prevented from shunning their work, by a back brace shewn particularly at T, plate XIV, which, by a wedge at its extremity, can be adjusted so that the lantern may be brought to a proper depth in the dead wheel fixed round the lower kirb F of the cap.

The numbers of the iron wheels for turning the cap are as follows:

The dead wheel upon the lower kirb F, is made in sixteen segments of fourteen teeth each, making 224; the lantern pinion working therein six leaves; the crown wheel upon the top of the main lantern spindle three feet six inches diameter, number, ninety-six teeth; the nutt or pinion turning it six leaves; the contrate wheel at the top of the oblique spindle, that is driven by the sail wheel pinion, two feet diameter, number seventy-two; the pinion upon the tail vane spindle, to drive the above number thirteen.

The axis of the tail vanes is intended to be a little oblique to the middle line of the cap, as shewn in this plan, that the main sails may be canted a little from the wind's eye, the right way, and the long oblique spindle being divided near the middle by a handle, (the arm A releasing at pleasure by a joint), the mill may be turned in a calm by hand.

OIL MILL, AT HULL.

EXPLANATION of the design for an oil mill, for Mr. Mayson Wright, to be worked by water raised by a fire-engine, at Hull, by J. SMEATON.

Fig. 1. shews the water-wheel in front, with its penstock.

Fig. 2. represents the general design of the work, the water-wheel being seen end-ways.

Fig. 3. represents the main spur-wheel in front, with the manner of fixing it upon the square flanch upon the iron axis.

N. B. The whole of the machinery being drawn true to a scale, the explanation will be confined to such things only as do not obviously appear from the several drawings or measures thereon.

Further explanation of fig. 2.

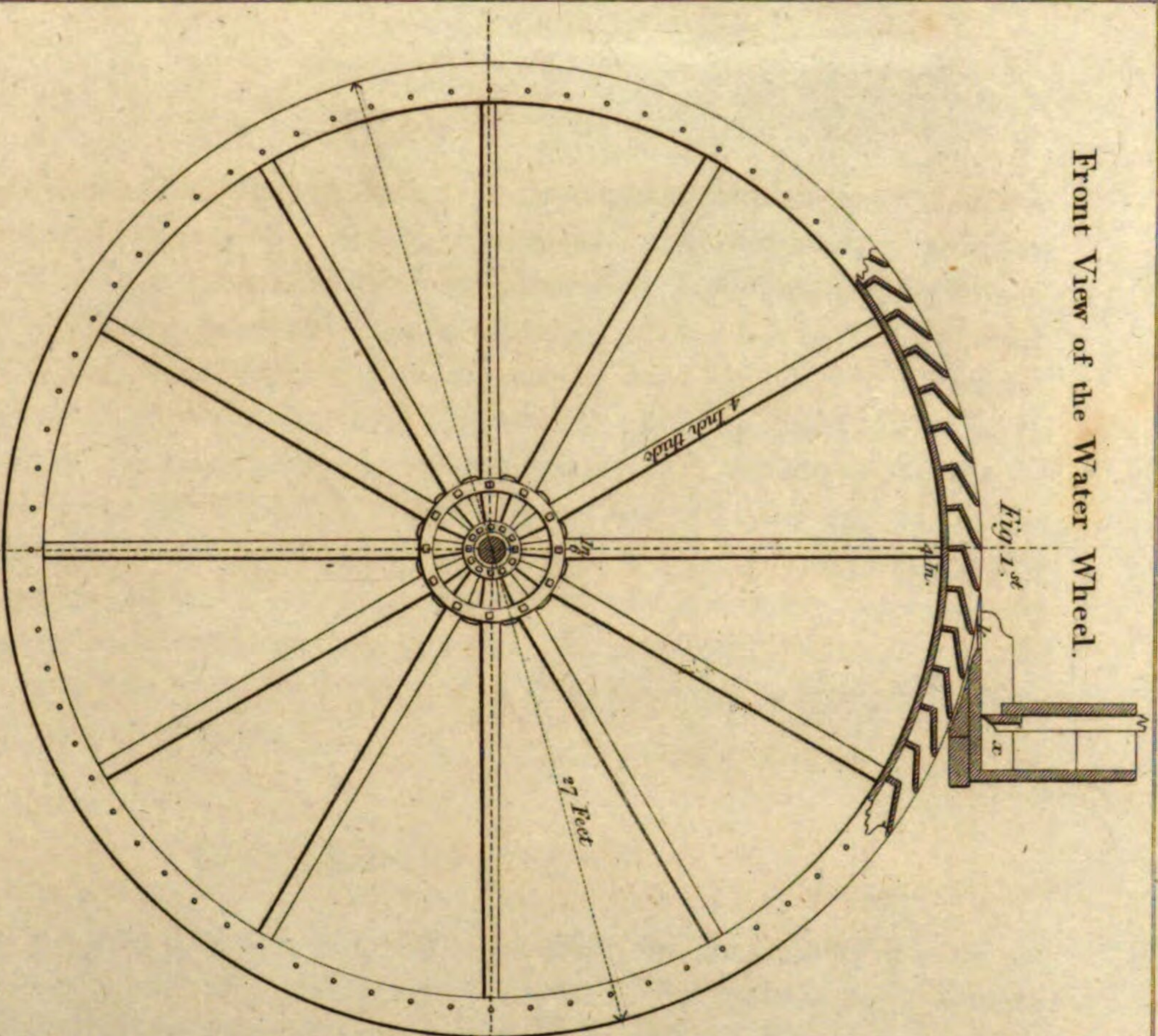
The axis of the water-wheel is supposed to be parallel to the length of the house, and the plane of the wheel to be parallel to the cross wall that separates the engine and refining-room from the great building; this view being seen from the side next Hull. So much of the floors and interior walls of the main building as will interfere with the work, is to be removed, and it is to be noted, that by lengthening or shortening the tumbling axis, the stones may be set at any distance, at pleasure, from the water-wheel.

The head-stock at a may be rested upon the said cross wall, if it proves sufficiently founded, and of strength to break a hole therein; otherwise a new head-stock wall had better be erected parallel thereto.

b, shews the section of a beam to reach across the building, in order to support the upper gudgeon of the axis of the stones, and c is a rider bolted to it, to carry the gudgeon of the tumbling axis.

The

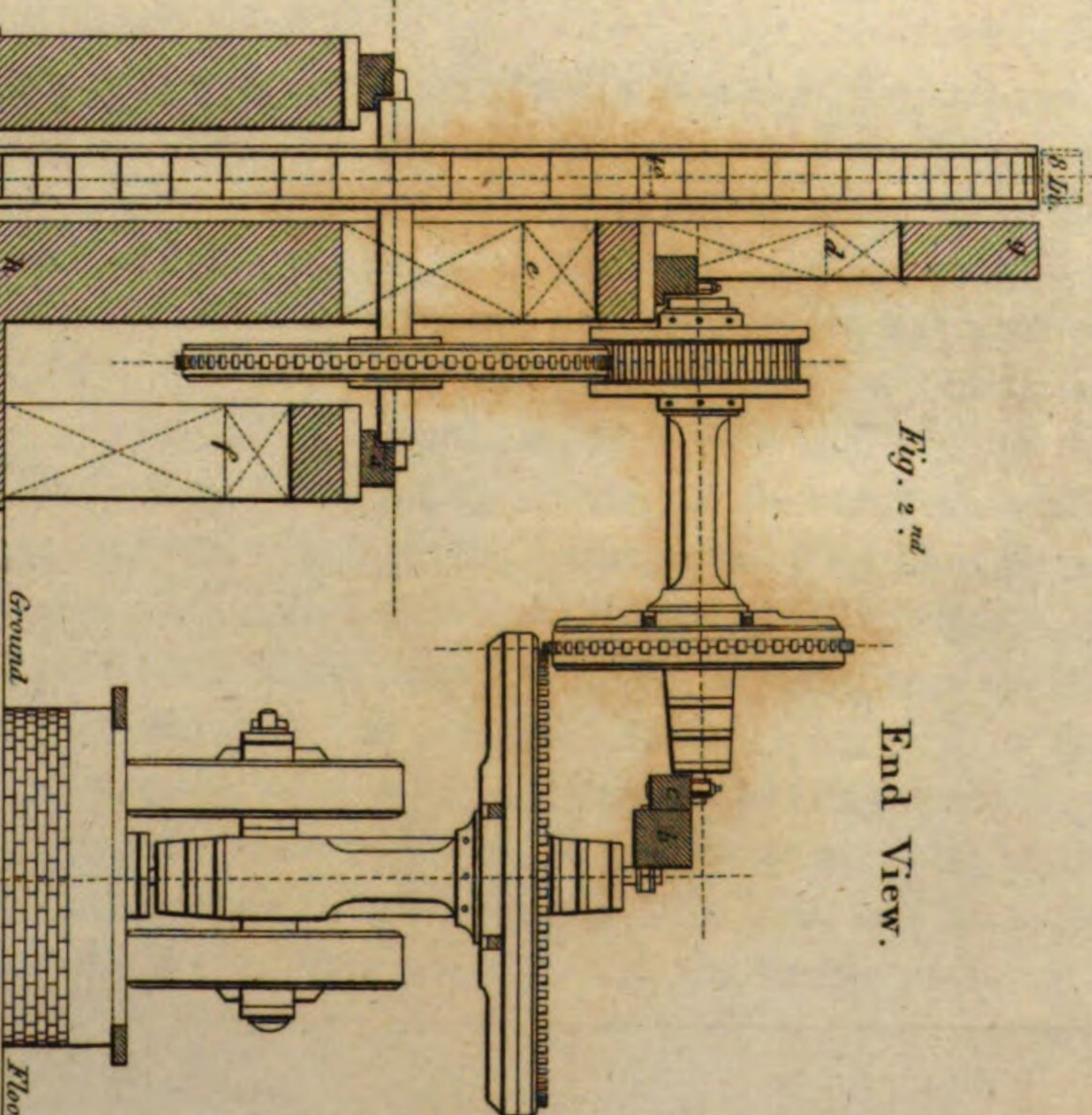
Front View of the Water Wheel.



Design for an Oil Mill for Mr. M. Wright at Hull.

Fig. 2nd.

End View.



Scale of Feet.
0 1 2 3 4 5 6 7 8 9 10 Feet.

Great Spur Wheel.

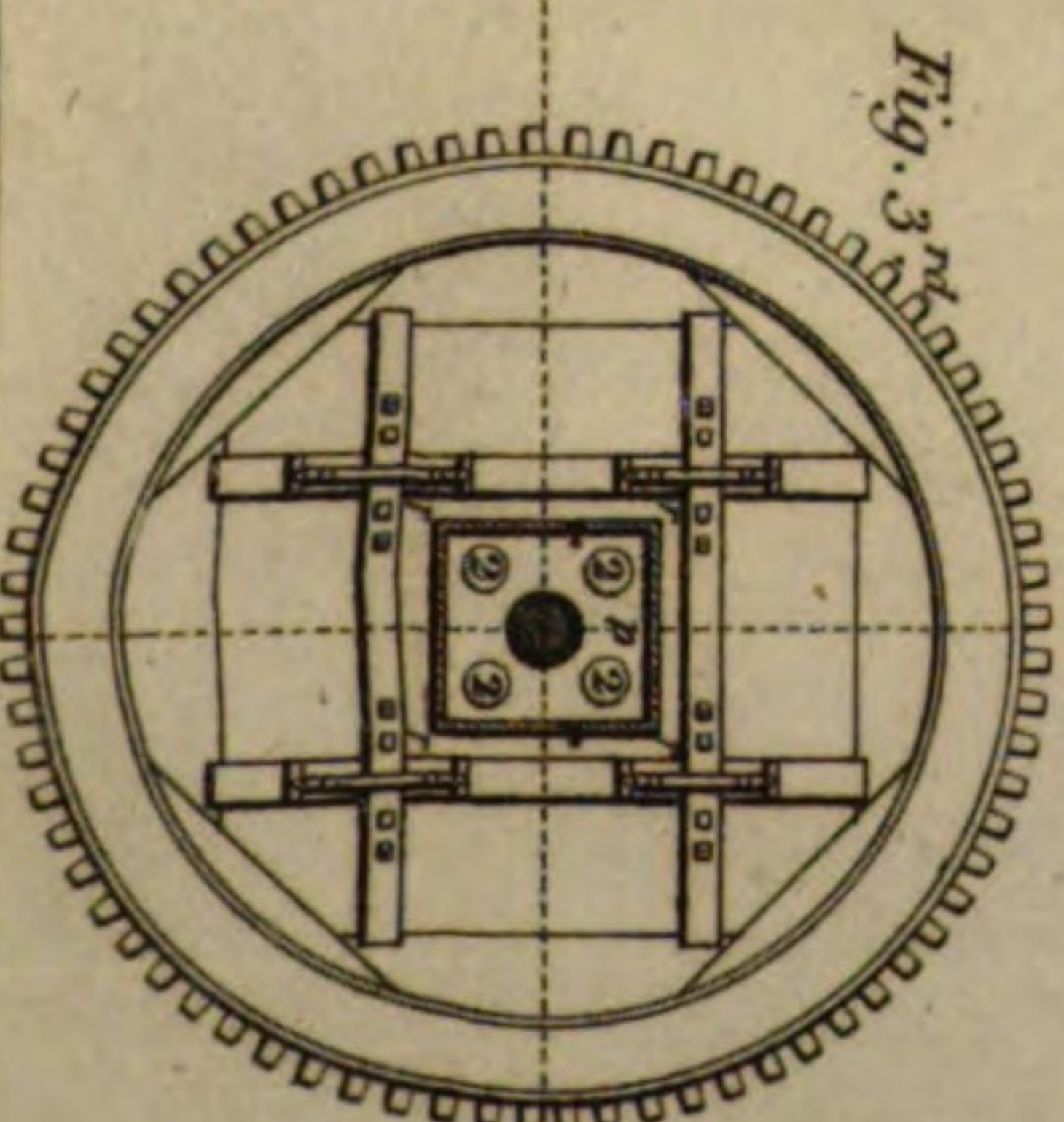
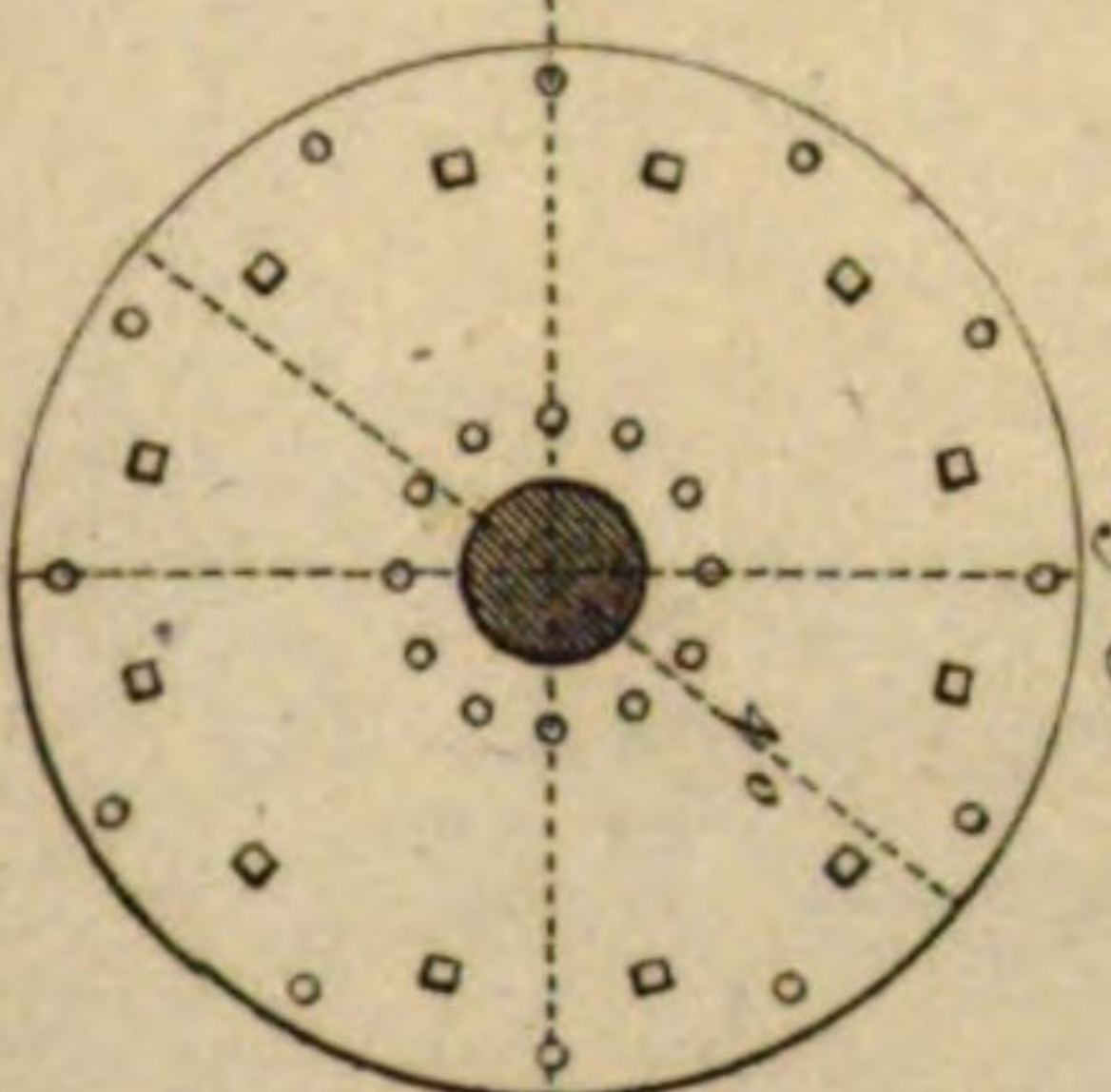


Fig. 3th.

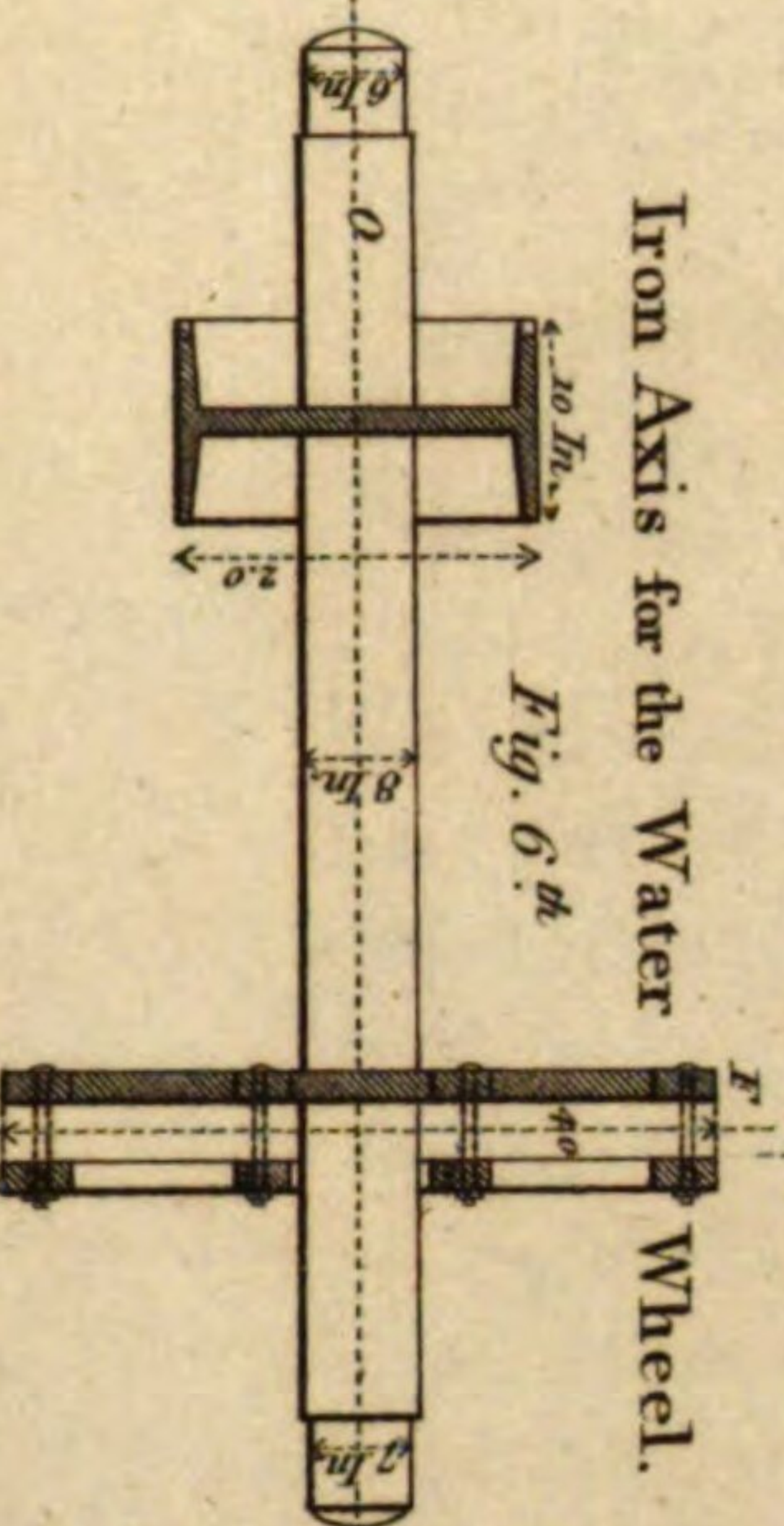
Fig. 4th.

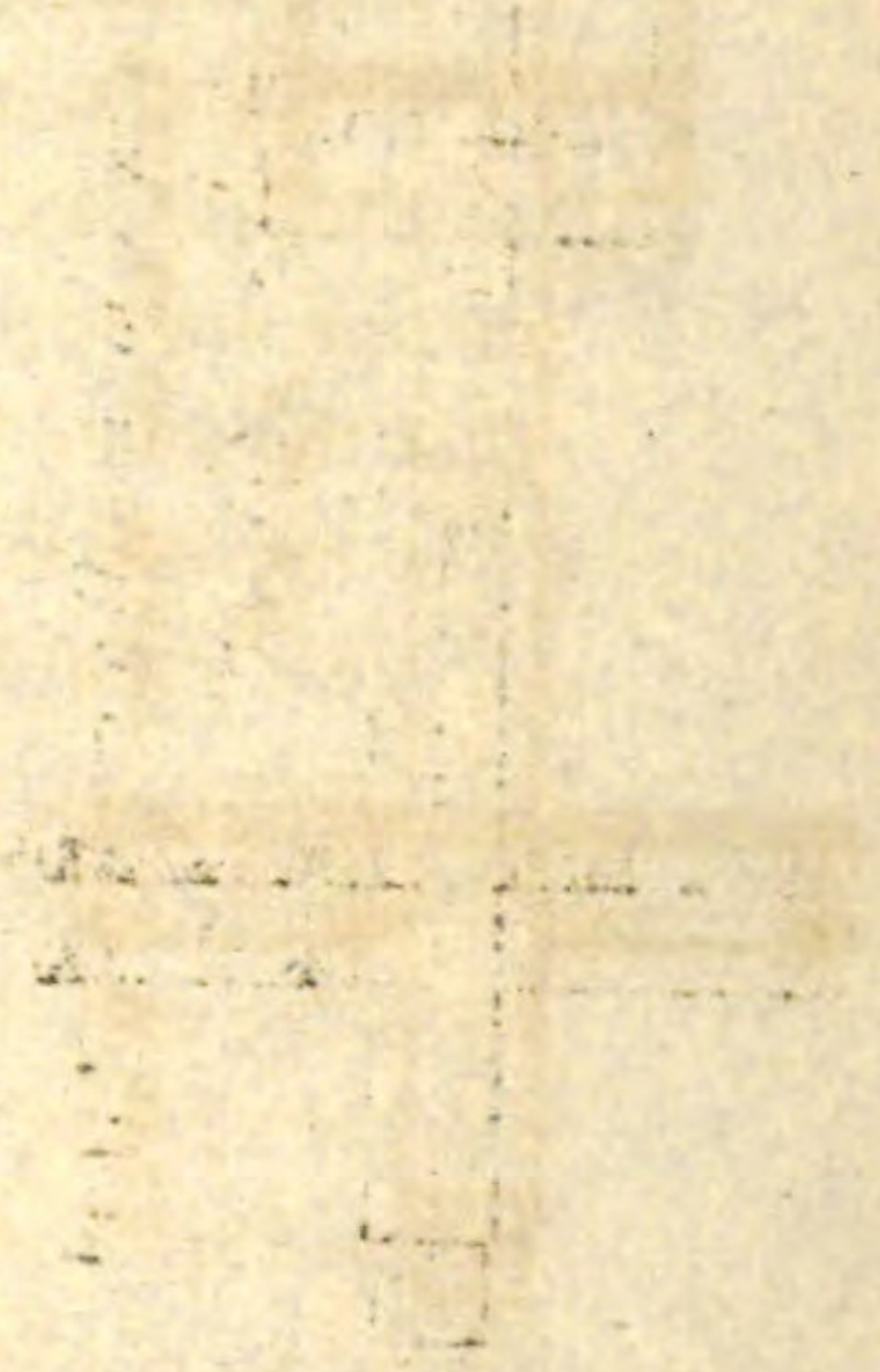
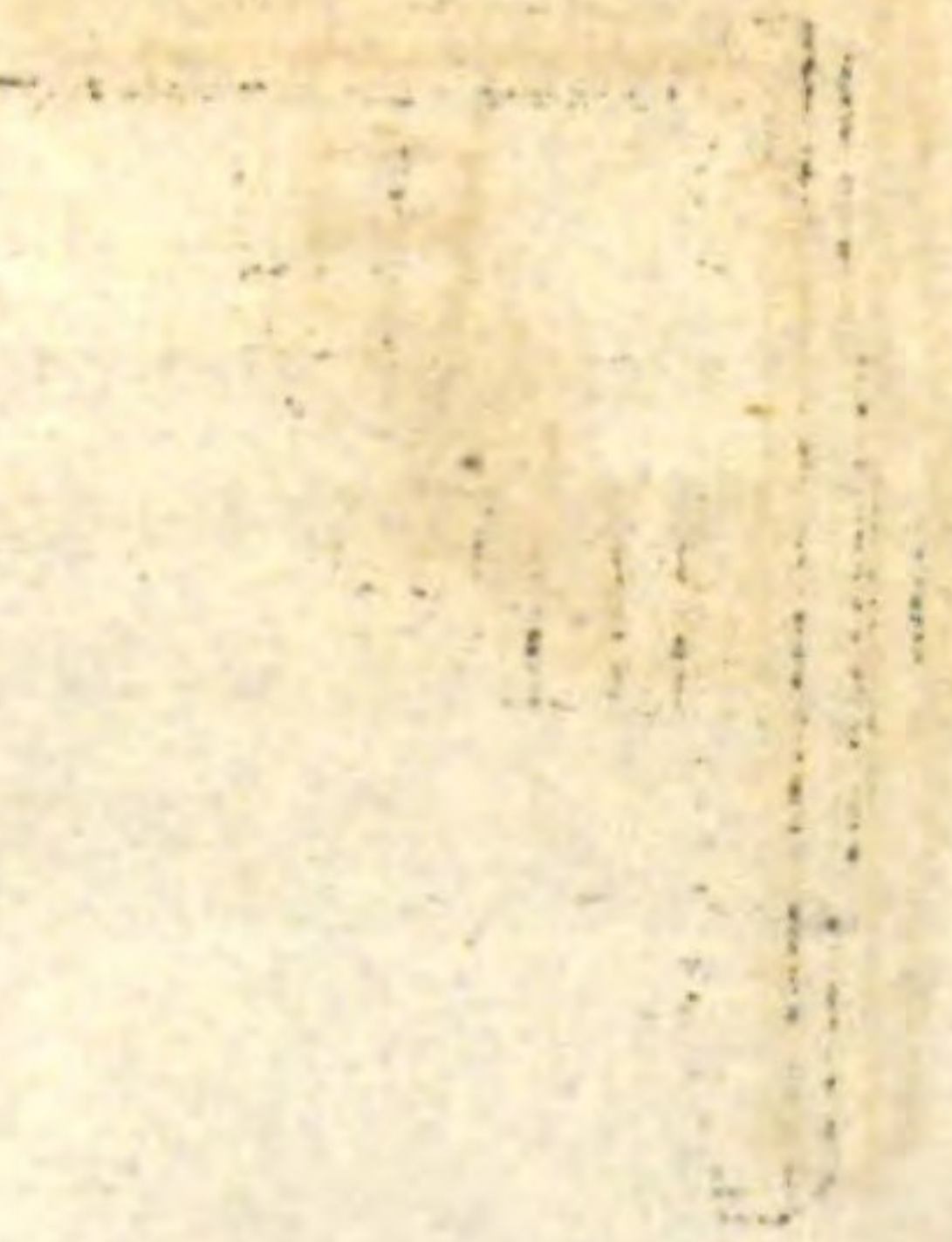
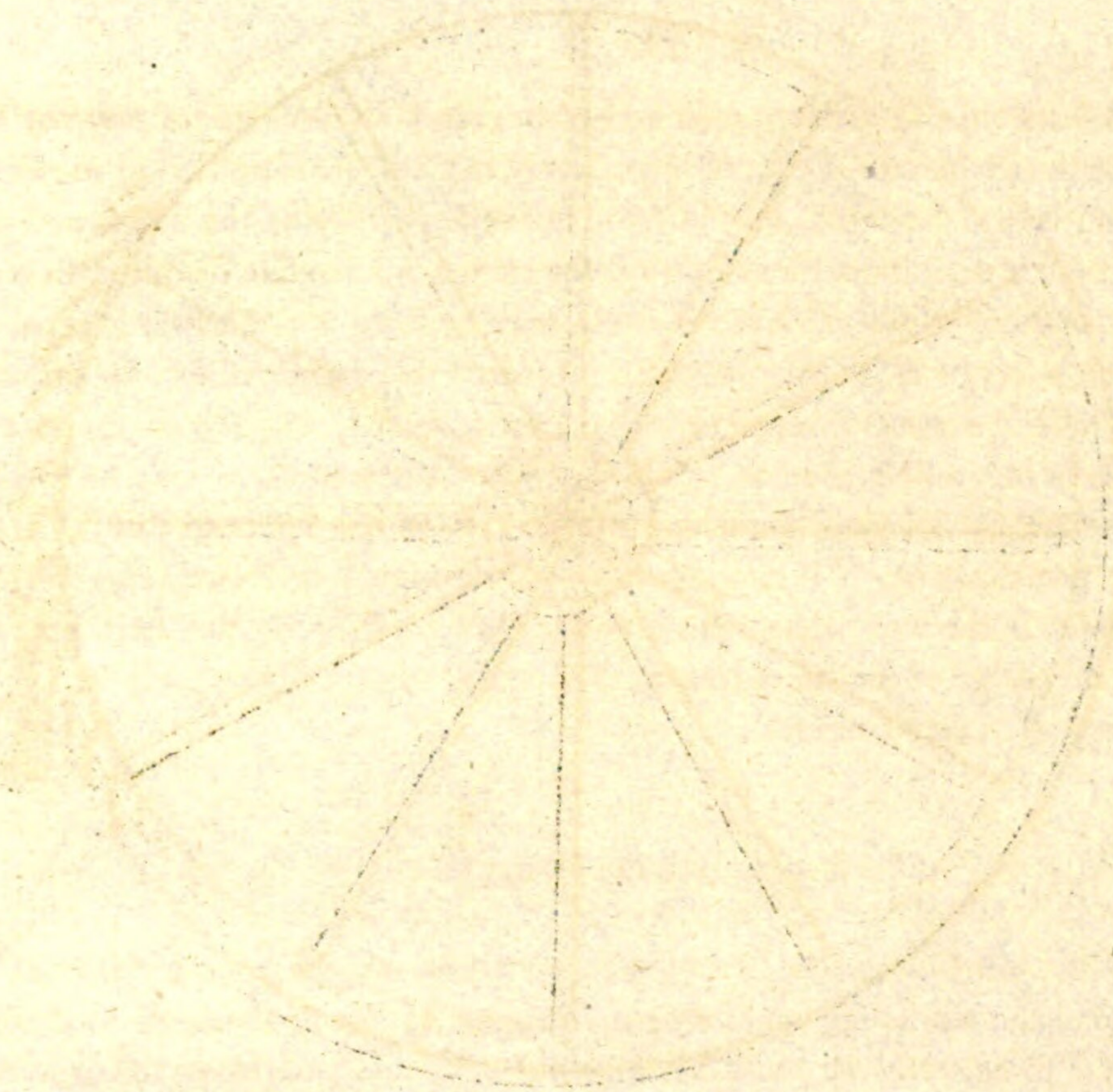


Iron Axis for the Water

Wheel.

Fig. 6th.





The unshaded spaces *d e f*, are supposed arched openings in the walls, of three or four feet in width, the lines whereon *d e f* are respectively marked are supposed in the spring of the arches; and it is to be noted, that in some convenient place of the water-wall *g h*, an opening is to be left near about the height of the centre, on one side or other, in order that the shield boards of the wheel, next the wall, may be fixed and afterwards repaired. The raising of the water-wall to the height represented will be necessary, in order to prevent the splash of the wheel from annoying the inner works, and also to support the penstock on cross beams rested thereon. The height of the bed stone may be at pleasure higher or lower, by varying the length of the axis of the stones to suit it, as also the height of the ground floor, if it happens to be a little higher or lower, respecting the surface of the water in the well, than here drawn. The press works are here omitted, as nothing is intended out of the usual course, Mr. Wright himself being the best judge of the conveniency of their situation.

Further explanation of fig. 1.

This view of the water-wheel is supposed to be taken on the contrary side of the wheel to that where the works lie, and shews the manner of fixing the arms to the iron axis, being bolted on between the great flanch on one side, and two strong cast-iron rings on the other; the intermediate spaces being filled up by drift wedges or chocks, the angles of which being somewhat obtuse, they are hindered from starting by wooden pins or keys, that stop against the inside of the great ring, and go through the chocks and the flanch. The side of the wheel descending will, therefore, be to the west, in case the stones are chosen to go round with the sun, and the penstock is supposed to be supplied by a square wooden pipe or trunk, proceeding from the reservoir, and in the direction of and parallel to the axis of the water-wheel, and consequently will enter the penstock sideways; the clear opening of this trunk in the inside is shewn by the space *x*, here represented on the far side, but in reality entering by the near side, which in this section is supposed to be removed. At *k*, in the bottom of the sheet of the penstock, is shewn the edge of an iron plate, intended to make the water deliver clean, and convey it nearer the centre of the wheel, without losing height; the width between the two cheeks of the shoot, whereof *k* marks the far one, is eight inches, and this is the breadth of the iron plate, being somewhat rounding at the extreme and most projecting in the middle. When the water has passed the middle of the wheel at bottom, it is to be conducted by a quarter-round turn, through the cross wall into the well, and from the centre of the wheel should gradually deepen from one inch, that the bottom of the conduit

duit is supposed to be covered with water to six or seven inches, or even twelve on entering the well.

Further explanation of fig. 3.

The centre circle is a section of the iron axis of eight inches diameter, the four circles round it are holes through the flanch of the main cog wheel; the square surrounding that is a hollow square of cast iron, two feet outside and ten inches in length, supported in the middle of its length by the said flanch; the square space between the said iron square and the arms of the wheel, shews what is occupied by the blocking and wedging, being three inches on each side, in order that the arms may be separated to the distance of two feet six inches. The plates shewn upon the crossing of the arms, are upon the side that is cut, in order to bind each firm together, the plates therefore on the far side lie the contrary way; the rest of the construction of the wheel is by backs and facings, in the usual way.

The other figures exhibit particular designs of the cast-iron axis, and the parts relative thereto, wherein

Fig. 6, shews the axis itself, with the round flanch F, and its two rings, as also the square flanch G, and its box in section.

Fig. 4, shews the two rings, l the bigger, and m the less, relative to their sections, marked with the same letters in fig. D.

Fig. 5 is the great round flanch seen upon the flat, wherein the holes are those for the keys or pins to pass through to keep the chocks and wedges in place.

The square flanch and box, as seen end-ways, of the axis, are represented in fig. 3, wherein p is the square flanch, q four holes through it, principally to facilitate the casting, r r r r is the edge of the square box, whereon the main cog-wheel is wedged, in the same manner as upon a square wooden axis.

GENERAL OBSERVATIONS.

The quantity of water furnished by the fire-engine being at present no more than 274.3 wine gallons per minute, the work done thereby can be expected but little to exceed

exceed the power of two horses yoked at once, that is, to turn the stones somewhat better than four turns per minute, with a full charge as in horse works; but as it is said that stones of this kind do their work in the best manner when they are made to revolve about ten turns per minute, and as they cannot be expected to revolve at that rate with the present power, it is most likely Mr. Wright will think proper to increase his power; I have, therefore, thought it good to adapt the numbers in such a manner as to be suitable when a power sufficient is procured, to make the stones revolve their full pace of ten turns per minute; and in the mean time I would propose to diminish the charge or quantity of feed put on at a time, till the stones will make six or seven revolutions per minute; this, perhaps, may not conduce to increase the produce of the work beyond the common charge at the horse pace, though, if any difference, I expect the way proposed will be for the better. But I apprehend it will be necessary, on account of giving a proper velocity to the water-wheel, for, in order to give the stones ten turns per minute, it is necessary that the water-wheel should revolve slower than the stones; and, therefore, according to the proportion assigned, when the stones revolve at four turns per minute, the water-wheel will be under $2\frac{1}{2}$ turns, a pace so slow that I can hardly expect it to move regularly or equally forwards; it will, therefore, be proper to diminish the charge till the wheel moves regularly and takes its water agreeably, which I expect will be when the water-wheel makes about four turns, and, consequently, the stones about six or seven. But, in case Mr. Wright should fully resolve not to increase his power, so as to make the stones revolve nine or ten turns with a full charge, there is nothing to be done but to make the wallower and spur-wheel upon the horizontal or tumbling axis, of equal numbers.

To increase the power so as to make the stones revolve ten turns per minute, with a full charge, and to do work in proportion, will require an engine that will raise $2\frac{1}{2}$ times the quantity of water that the present engine can do, an improvement that is totally out of nature to make with the present engine; but, with an engine properly constructed, of twenty-five inches cylinder, I can undertake to raise to the height of thirty feet 1000 gallons, wine measure, per minute, with the expense of 1 cwt. 3 qrs. coals per hour; and I do apprehend, that if a new engine were set about in conjunction with the mill, or proper conveniencies left for placing it, that such an engine would be made for £350, or thereabouts.

J. SMEATON.

London, 15th March, 1776.

LEAD HILLS WORKS.

The REPORT of JOHN SMEATON, engineer, upon the state of the powers employed, and capable of being employed at the Susannah Vien, at Lead Hills, for unwatering the low workings thereof.

AT the request of the court of directors of the Scots Mines Company, on the 27th and 28th of August last, I carefully viewed every thing both above ground and below, that I conceived could conduce to give me a thorough knowledge of the circumstances attending the Sufannah Vien at Lead Hills, so far as related to the drainage of the water from the low soles or low workings of that vien, both with respect to its present and future prospect.

The principal circumstances attending this mine in the respects mentioned, I found as follows :

But I must first premise, that the season preceding my being there was remarkably dry and warm, and which, as I was informed, had been very particularly the case in the quarter of Lead Hills, and, indeed, the remarkable dryness of the moorish soil that there abounds, in a great measure shewed the same thing, the drought being continued to, and during the time I staid there, which was till Monday the 30th of August.

The lowest level that now drains this mine, which issues out near the company's smelt mill, is called the Poutchill level, and by it issued in that dry season near upon the whole water that is collected in the district, its quantity was then considerable, amounting by my gage thereof to no less than 205 cube feet, that is, to twenty four hogsheads, or six tons per minute.

There is now bringing up a low level at the random of twenty-two fathoms below the Poutchill level, which, coming from a lower part of the burn or rivulet, by which the waters of Lead Hill make their departure, will flank the vien, and enter it near to a right angle ; this level is carried directly towards that part of the vien where the deepest workings are, so that when this level is finished, or brought up to the vien, the whole of the water, or nearly the whole, that now makes its departure by the Poutchill level's mouth, can be let fall into the low level.

Of

Of the water that now issues from the Poutchill level mouth, a part of it is gathered upon the surface, being the collection of a great number of springs and waters issuing from old upper workings, which are collected by a water-course that extends upon the surface several miles in length, and is ultimately conducted to the top of a shaft near the mouth of Porto Bello level: it there falls down by different stages to the amount of twenty-nine fathoms, before it reaches the top of the wheel of the present bob engine, which is employed in raising such water from the depth of thirty-one fathoms, as has been unloosed in the mine below the random of Poutchill level.

This surface water I gaged, as I then found it near the shaft, where it goes underground, and found it amount to seventy-seven cube feet per minute.

The whole water issuing by Poutchill level, nor this part of it in particular, was never known to be less than it was at the time of my view, and which, on that account, was very fortunately timed; yet this surface water gave power and velocity to the present engine more than sufficient to draw the water, it being upon the snore, or drawing air, so that it did not fill its barrels by about one quarter part, as I judged it.

The water arising underground is pretty constant; yet, like most other springs, is increased by the winter's rains, and the surface water much more; for the discharge of the Poutchill level in the month of April, being measured in a cistern, amounted to more than double the quantity now assigned by me, the operations confirming each other; but in general, when the water underground is increased, the surface water is still more so, so that the engine moving with greater velocity, is generally competent to draw its water, except during the frosts in winter, which often continue long there, when the surface water becomes frozen; for though it in general proceeds from springs, which coming out at forty-five degrees of the thermometer, may be called warm, when compared with frost; yet by running for so many miles in an open leet, exposed to the frosty air, it at last submits to the cold, so as to prevent any water from getting home to the engine, the consequence of which is, that during those frosts, which I am informed continue frequently for four months in the winter, the workmen are totally driven from the low workings.

This engine has a twenty-four feet water wheel overshot, and draws a column at two lifts of thirty-one fathoms, the bores of the pumps being $7\frac{1}{2}$ inches working barrels; it makes a five feet stroke, and when I saw it, made $5\frac{1}{2}$ strokes in each barrel
per

per minute; which, allowing for air then drawn instead of water, amounts to 380 cube feet per hour, that is, to about $11\frac{1}{4}$ tons, which, together with the surface water from the tail of the wheel, is delivered into the Poutchill level, and makes a part of the water thence issuing.

Below the level of the engine foot, the works are carried down in two separate places, from one of which they are extended to the north, and from the other to the south, there being betwixt the two a check in the vien, where the two checks are so close together as to make a water tight joint, so that it acts as a dam, and prevents the water of one set of workings from affecting the other, while both can be cleared by the engine; this check thus keeping the workings separate, is a real convenience, as either may be worked without drawing the water out of the other.

One of these workings goes down eleven fathoms, and the water thence arising, which is by far the most considerable, is drawn by hand pumps. This work was full of water at the time I was there, the pumps not being at work; but as the water was running out at the top of the pump, which I was informed was as near as possible the same in quantity as if drawn by the pump, it would therefore be the same to my measure thereof as well as the engine, and which I found to be 206 cube feet per hour.

The other was clear of water, which produced much less, and was drawn by tubs from the depth of fifteen fathoms, the amount of which was then at the rate of seventeen cube feet per hour, so that the whole growth of water arising below the engine pump foot, amounted to 223 cube feet per hour, which, deducted from what the engine then drew, viz. 380 feet, will leave 157 cube feet per hour, arising between the Poutchill level, and the engine pump foot.

When I was there they were preparing to put in an additional engine, whose water wheel was of thirty feet diameter, and eighteen inches in the sole; with this engine they propose to sink thirty fathoms below the present engine pump foot, that is, fifteen fathoms below the deepest workings at present in this vien. This engine is to receive the power by placing its wheel above the present one, so as to occupy a part of the twenty-nine fathoms that the surface water has been described to descend from the surface to the top of this present wheel; and after delivering its water from the tail of the new wheel, it is then to be re-conducted upon the present wheel, and do its office as at present; but the pumps which are intended to be of seven inches bore, are to be placed

placed in a pump funk by the side of the other, and to raise, not only the water that is raised from the low soles by the hand pumps and the tubs, but such as may arise in going still deeper, to the depth of thirty fathoms below the present engine foot.

Having now described the present state of things, I proceed to give my opinion thereon.

I understand from all hands, that the putting in of the present engine is to be considered as a temporary expedient to draw the water now drawn from the low soles by the hand pumps and tubs, till the low level is got up to the vien, which may possibly take three or four years; after that, we are to consider what kind of power this will afford us, when the water issuing from the Poutchill level can be let fall as a power from that level twenty-two fathoms down to the low level, the draft from the low soles being then relieved by twenty-two fathoms in the perpendicular rise; for then the deepest of the present workings will be only twenty-four fathoms under level, and the pump foot of the intended new engine will be no more than thirty-nine fathoms, which to the present level will be sixty-one fathoms; that is, whether there is such a kind of probability of then wanting a sufficient power from this fall of water as to make it necessary now to prepare conveniences for the erection of a fire engine.

	Cube feet per minute.
The quantity ascertained by me to proceed from Poutchill level, the 27th September, 1779,	205
The surface water ascertained the same day for turning the engine,	77
Also, what the engine drew from the low soles, 380 cube feet per hour, that is, $6\frac{2}{3}$ cube feet per minute, which, to avoid fractions, call	6
	83
Will remain water raised in the mine and its communications, that will not be subject to frost,	122

Which quantity, of 122 cube feet per minute, being let fall twenty-two fathoms, and acting upon an engine properly constructed to be acted upon by the weight of the whole column, will be equivalent to the power of a fire engine of thirty-six inches cylinder, and this in its weakest state, and no advantage supposed to be received from the surface water, which, if we take into the account, will, for the greatest part of the year, be equivalent to a fire engine of forty-five inches cylinder; but the constant power equivalent to a thirty-six inch cylinder would raise double the produce ascertained of the

the present engine from a depth of 128 fathoms below level, which is 104 fathoms deeper than the present lowest workings.

It is probable, that in increasing the extent of the present workings of the low soles along the vien, more water will be cut, and as they go deeper, still more; but if all the water that can be collected at thirty-fathoms below the level now bringing up (that is, six fathoms below the present lowest workings), is there intercepted, and raised to that level, without being suffered to go down, it is probable, that the water raised under that level, will be considerably less in quantity than what is now raised by the present engine; for, after a certain depth, depending on local circumstances, it is a general observation among all miners, that the deeper you go, the less water you raise, so that it is highly probable that a less power than is equivalent to a fire engine of thirty-six inches cylinder, will clear this vien of water to as great a depth as it will carry lead.

It is remarked by Mr. Milne, who was so obliging as to furnish me with copies of Mr. Sterling's letter to him of the 9th of January, 1779, and his answer thereto of the 10th of February following, that the principal appearance of water was at the issuing of the Poutchill level, from whence he concludes, that the principal part of the water that has been raised in these mines is now dropped down to that level, as being the lowest point to which it can descend, which observations I must confirm; he, therefore, concludes, that nature following the same course, when the low level is brought up, and the vien opened, the greatest part of all the water will also find its way down to that level, and of consequence there will be an end of that power, arising from the descent of the Poutchill level water into the low level, which was insisted upon as a sufficient power by Mr. Sterling, and the effects of which have been more particularly calculated and ascertained in what precedes; and this being supposed to be the case, as the ground to be worked upon is very hard, and will take several years to sink a perpendicular shaft from the surface down to the deepest and most valuable part of the present workings proper for a fire engine to be placed upon, it is now time to begin such a shaft, that it may be ready when it shall be wanted.

This, undoubtedly, is a question of a very serious import, and demands a critical investigation how far the subsidence of the present water is likely to take place; because, if it does in the manner and degree suggested by Mr. Milne, there is an end of all reasonings and calculations about its power and effect. 1st. That in laying open
the

the vien, the water raised therein has in a great measure got down to the Poutchill level, being now the lowest level to which it can descend, is certain: but I apprehend that this has been owing to there being no motive at the various times at which the springs have been cut for keeping the water up, but it has been suffered to descend to the low level as the shortest way of getting rid of it, and the water rising in a great variety of places, it is now impracticable amongst old workings to collect it at a higher random.

2dly. I understand that a great part of the water that now issues at the Poutchill level mouth is not the produce of the Sufannah vien, but proceeds from the old works of several other viens that have been unwatered by a cross level taken out of the Poutchill, and which now, and for a course of years past, have issued their water invariably here, and consequently can be subject to no change by the future workings of the Sufannah.

3dly. The Sufannah having been worked as far into the mountain as the boundary, the whole of the springs rising in or above the level of the Poutchill are collected therein, and could be kept upon that level by an artificial bottom, though the present natural bottom were cut away; it is therefore only such springs as arise in the very bottom of the level that have passages under the floor of that level, and inverted syphon-wise, proceed from higher sources; I say it is only springs of this kind that can be affected by under-workings, and which kind of communications we must apprehend can scarcely exist, except near the boundary, where the ground is whole in the direction of the vien; for, as the strata stand edgeways here, or parallel to the checks of the vien, very little water can make its way crossways of the checks: it follows, therefore, that very little of the present water would be let down, though the vien were worked to the extent of the boundary under the random of Poutchill level, provided the bottom were left whole, or made good artificially, where any chasm or openness might occur.

4th. The present low level being carried flankways to the vien, there is very little chance of its cutting any water which has communication with the water that now makes its way into the Poutchill level.

From all these considerations taken together, I am induced to think that proper care and attention being paid to the subject, it will only be a very small proportion of the water now issuing from Poutchill level, that will get down to the low level, when brought up to the vien, except by passages cut for the purpose; but from what

what has been established, even if half of it were to get down to the level, yet the other half would be a power so respectable, as to be capable of drawing as much water as now arises below the Poutchill level from a depth of 128 fathoms, and double that quantity from half the depth, which would still be forty-four fathoms below the present low workings, and will doubtless last several years; and even this power will be of that consequence where coals are at a considerable distance in a mountainous country, that it will be very well worth while to employ a power of water as far as it can be employed, and build a smaller fire engine in aid of the water engine, whenever that shall become overpowered.

But here it may be said, that since the placing of a fire engine underground may be impracticable, or at least inconvenient*, for the reasons given by Mr. Sterling, and as it will doubtless take several years to sink a perpendicular shaft from the top of the mountain, in case a fire engine should become necessary, contrary to our present speculations, what is then to be done? Is a valuable mine to cease work till a shaft can be sunk? I answer no.

The argument here is to time, not expense; because, if a shaft could be sunk in the same time that the engine was building, though the expense of the shaft would be the same, it would, doubtless, be proper to defer so as to begin both together, therefore saving the expense of the shaft. I would sooner undertake to put up a fire engine of any size that might be required, without either placing it underground, or sinking a shaft from the surface, than to place it upon a shaft subject to the expense, though it could be done in a day.

In short, I would place my engine at the tail of the low level, and work my pumps in a pump put down to the low workings by a sliding spear through the low level, and such a pump must, in effect, be sunk for placing the pumps of such an engine or engines as must be used, previous to the execution of any engine upon the twenty-two fathom fall.

It may be now time to say what kind of a water engine I would recommend for this new fall of twenty-two fathoms.

I believe I may lay it down as a certainty, that no engine has yet been invented that surpasses the bob engine for the miner's use, when well proportioned and constructed, and

* A fire engine deep underground has been in use some years past in the coal mines of Whitehaven.

and in such situations as it is adapted to, but as, particularly underground, it would grow very cumbersome, if erected with a water wheel exceeding thirty feet, it follows, that in the height of twenty-two fathoms, it would take four such water wheels and engines, one above another, to exhaust the power, or, in other words, to receive the full benefit of this fall, and which altogether would become a very complex and expensive assemblage of machinery.

Now, as it frequently happens in mines, that very great falls can be obtained, and but small quantities of water, then, as has been said, the bob engine taking in but five or $5\frac{1}{2}$ fathom with convenience at one stage, will be subject to a considerable expense in the erection, and do but little business; whereas, if the power of four, five, or six such wheels could, (where there is fall enough) be united in one machine, this would avoid not only great expense in the erection, but the complexity, weight, and incumbrance of several machines, and therefore it has long been a *desideratum*, which several have formerly attempted in different ways, but without particular success; this proposition, however, was about fourteen years ago happily accomplished by the late very ingenious Mr. William Westgarth, at Coal Cleugh, in Northumberland, to the lead mines of which place he was principal agent for the late Sir Walter Blackett.

This engine acts upon a simple statical principle, not unlike the fire engine, substituting the weight and pressure of a column of water, for the pressure and weight of a column of the atmosphere, so that as the column of water that may press upon one end of the balance beam may be of any perpendicular height, a fall of twenty, or even sixty fathoms, may be taken to one machine, and as it is not requisite that this fall should be in a perpendicular line, but acting through a pipe, may be bent in any angles that suit the place. This machine very particularly adapts itself to the frequently occurring circumstances of lead mines.

The machine mentioned has been constantly at work ever since its erection, and I believe still is, without ever being subject to any material disorder, other than common repairs. Some others were also erected in the same neighbourhood by the same ingenious person, some of which are still working, and the others not, owing to the mines ceasing working, or the water being relieved by bringing up a deeper level*.

* One upon this principle I have myself erected that has now been at work ten years, and is likely to continue.

It is, therefore, Westgarth's statical engine, mentioned in the papers before me, that I would advise to be erected upon the twenty-two fathom fall, which working with the quantities of water specified, is capable of producing the effects I have calculated upon.

This engine has also this further advantage; like the water wheel, it has, according to its size, a certain rate of working, which it cannot exceed, but will perform in proportion to any less power applied; so that if it is calculated to go sixteen strokes per minute with a given quantity of water, and this be reduced to one-fourth of the quantity, it will not stop, but make four strokes per minute.

I come next to make mention of the engine now at work, and that erecting: the present working engine at the time, and for the purpose it was erected is not amiss, the size of the water wheel being properly adapted to the quantity of water, and the pumps to both, and I may say the same thing of that now erecting: it were, indeed, to have been wished, that in the order of things, each engine had been in the other's place; for then, as the new one will be the more powerful, each would have had a quantity of work to do, proportioned to its powers, and the present one, which is the weaker engine, on account of the less diameter of its water wheel, would have had only its water to have drawn from the low soles, which, as has been shewn, is less by 157 cube feet per hour than what is drawn by the present engine from its own pump foot; but the fact is, it is not easy, but indeed very troublesome, to change the situation of such an engine underground, without stopping the works, and as long as the old one can manage its water, it is no fault that the new one should be stronger; for, however powerful, it can draw no more water than there is to draw, and as it appears from what has already been stated, that the present engine was capable of drawing about one-fourth more water than there was to draw, it is to be hoped, that in the interval of the low levels coming up, there may not be more water cut in addition to the present, by an extension of the work of the low soles, than what may still be mastered by the present engine; yet, if this should happen, there will be wanted a second new engine in aid of the present one.

Some little aid may be indeed drawn from the new engine, or by shortening the present engine pumps, and lengthening the other; but as this will take up time, during which no water can be drawn, I would rather in that case recommend the putting in of one of Westgarth's engines, that would at once do the business of them all,

all, and if necessary, exhaust the whole power of the surface water that now falls in the whole thirty-three fathoms, of which the power of twenty-eight fathoms is now lost, and after the new wheel is put in, above twenty will still remain unemployed; indeed, had I been consulted before any material progress had been made with the new water wheel engine, I should have clearly advised one of Westgarth's, which, when erected, would have put the present engine out of employment. The advantage of such a powerful engine would have been great, even supposing the present machines to continue capable of mastering the water, because it would much sooner have cleared the mine after a stoppage by frost.

J. SMEATON.

Austhorpe, 16th October, 1779.

MILL

MILL FOR GRINDSTONES.

REMARKS concerning the mill for turning grindstones, and grinding blacking.

AS it was desired to adapt grindstones to the new boring mill, and thinking them better to be separate, I adapted the design immediately to the same head and fall of water, and I apprehend, that at all common times, there will be water enough for the whole, especially when the sluice is open to receive water out of Stenhouse dam-head, but as water, when there is plenty, may as well be taken from the forge dam-head, as any other, the design of this mill will equally apply itself to either, only converting the breast wheel into an overshot. However, for the single purpose of turning grindstones, the present plan will have the preference, in going more steady. Iron rings will not be needed for this wheel, wooden ones, of the common scantlings, viz. about six inches square, will be sufficient.

As the same patterns for the wheels and nuts as in the gun mill are proposed here to be made use of, I apprehend they will be done cheaper than of wood, but if otherwise, wooden wheels of equivalent numbers will do; also, if the practice of making iron axes for the water wheels, be found to recommend itself so far as to be equally cheap with wood, they may also be used here.

J. SMEATON.

Austhorpe, October 15th, 1770.

N. B. I suppose one pair of four-feet common mill-stones, cut with furrows, as for corn, will be sufficient for grinding the blacking, but as it will be very little more expense by lengthening the tumbling axis, and the hirst, to make provision for two pair, it may be adviseable to do it, as there is no saying what purposes may occur to employ them.

Upon the whole it seems adviseable to let all stand as they do, till the new mill be built, and from its performance the conveniences of the rest will shew themselves.

LIIM

BOCKING

BOCKING FULLING MILL.

DIRECTIONS for converting the larger water wheel of Mr. Nottidge's fulling mill at Bocking, so as to drive two stocks by geer.

1st. THE water wheel must be turned about so as to go the contrary way round, which may be executed three ways, the whole wheel and axis may be lifted out together, and the axis changed ends; secondly, if the wheel is made with clasp arms it may be unwedged, the axis drawn out, the wheel lifted out and turned, and the axis put in again the same way as before; or thirdly, the shrouds being taken off and changed side for side, the buckets may then be reversed, all the rest remaining as before.

2dly. The water wheel must be raised three inches and a half higher than at present, so as to have no more than two inches and a half tail water in dry seasons, and must be set as much down stream as possible.

3dly. It must be fitted up with a breasting sweep of wood, brick, or stone, from the centre of the wheel to the bottom, then carried level three or four feet, and then reconciled by a slope with the present floor.

4thly. The water must be made to go on to the wheel in a reversed direction to what it now does, which can be done without any material loss of fall. The trough at the proper point is made to divide, and its bottom to proceed on the same level as at present, on each side of the wheel, and from the trough of union the bottom rises five inches into the shuttle trough, the two being reconciled by a slope. The water wheel will then stand as follows:

	Feet	Inches
Tail water in dry seasons	0	2½
Height of the water wheel	12	0
The surface of the water at a full head above the top of the water wheel	1	1½
The surface of ditto above the shuttle trough bottom	1	3½

5thly. A spur wheel, of forty-eight cogs, at a five inch pitch, must be put on to the east end of the water wheel axis, to drive a lanthorn or wallower of twenty-three rounds, put

put upon the end of a tumbling axis lying upstream, which axis you have in your power to make of what length you please, to suit your convenience. In this you place your feet answerable to your stocks, according to your own method. Upon this axis, to give it a pleasant and steady motion, must be placed somewhere, a loaded wheel or fly, which the width between your upstream and down stream topsets will not admit to exceed five feet five inches diameter, and which will most conveniently be made of cast iron, of the square of five inches; it will weigh about half a ton, and you may have it cast all in a piece. The spur wheel and lanthorn I should also have had of larger dimensions if room would have allowed; but to make them wear longer and more kindly, it would be of advantage to put in a double row of cogs, which is easily done by putting on a facing on each side: this however regards only the length of time that the geer will last.

The best place for the loaded fly is between the two stocks; it seems to me that you may dispose of the spur wheel and lanthorn in the vacancy next east of the wheel, and as near as may be to the wheel; then to take off from the west side of the place for the two stocks by a new transverse timber, so much as only to leave room for one stock; this will leave you a sufficient vacancy between the cog-wheel and the stock, to run the loaded fly on the east side of the most easternmost transverse timber, to put in a new transverse on the east side of the loaded fly, and another as far east as will take in a place for the second stock, and this will still leave a considerable vacancy at the east end.

Respecting matters of convenience, in regard to the placing of the stocks, you must judge for yourself, and in regard to the thickness and strength of the parts, your millwright will, I doubt not, judge properly, but you must strictly adhere to the proportions I have given, because the performance depends upon it, and which done, you will find that the mill will not only go with much less water than in now does in dry seasons, but will also bear much more tail water in time of floods.

You must however remark, that where the gate draws so shallow, it is required to draw higher (to let through the same quantity of water) than where it draws lower.

J. SMEATON.

Austhorpe, 27th June, 1772.

FLINT

FLINT MILL AT LEEDS.

DIRECTIONS for weathering the Sails of the Flint Mill at Leeds.

THE lattice of the sails being composed of twenty-five bars in the scheme or scale of weathering, No. 1 represents the angle of weather of the point bar; No. 2 that of the 2d, and so on increasing to the 20th bar, the 21st being the same, and then gradually diminishing to the 25th, which is supposed to be at four feet distance from the centre of its weather, the same as the 16th.

N. B. If the angle for each bar is taken off from the scale by a bevil, between the line called the parallel of the axis, and the respective number of the bar, and this bevil applied to the leading side of the whip, the mortise being set off on each side the whip, will give its proper angle.

The weather of the leading board is to be somewhat different to that of the lattice for the sail cloth, viz. the leading board from the 25th down to the 12th bar, the board, &c. is to be nailed upon the leading ends of the bars produced as usual; but upon the leading end of the point bar, or No. 1, there is to be applied an angular piece or wedge, whose thickness at the head is one-eighth part of its length, and this being applied with its point next the whip, and fixed upon the face of the bar, will give the board a degree of weather at the point, more than the cloth by the angle of this wedge, this being supposed fixed, the rest of the bars Nos. 2, 3, 4, &c. are to be furnished with wedges growing gradually thinner, so as to end in nothing at the 12th bar, reconciling the 1st and 12th, upon which 12th, as before mentioned, the board fixes as common without any rising.

It will be necessary to attend minutely to these directions for the weathering of the sails and boards, the effect depends upon it, and however uncommon they may appear, the success will follow.

N. B. It will be proper to weather the face of the whip correspondent to the bars, from the point to the 17th bar, and then gradually to lose it in a square for the sake of strength. All other sides of the whip to be kept square as usual.

J. SMEATON.

Austhorpe, 29th April, 1774.

PUDDING

PUDDING MILL.

The REPORT of JOHN SMEATON, engineer, upon the powers of the Pudding Mill, in the parish of St. George, in Surry, near Blackfriars Bridge, for raising water for the service of the neighbouring parts of the town, and other purposes.

THE power of the pudding mill depends in a great measure upon the tide water that is taken from the river Thames into certain ditches or drains, that in a manner encircle this parish as well as intersect it in certain directions; this tide water is taken in by means of a draw gate sluice, which, when in spring tides it has flowed to a certain gage mark upon a post placed in the mill pond for that purpose, the sluice is put down to prevent the waters rising to such a height as would annoy the houses and premises of the inhabitants; the water being thus shut in the ditches to a certain height, it there remains till the water of the Thames has reflowed to three hours ebb, or thereabouts, when the floor or apron of the mill conduit begins to be sufficiently clear for the water wheel of the mill to begin to work, and then the mill gate or sluice being drawn, the water so pent up in the aforesaid ditches, is gradually let down upon the water wheel of the mill, and turns it for a greater or less time in proportion as the water has occasion to be expended at a greater or less rate, but in any rate in which it can be supposed to be consumed in doing business, it will or may be spent before the action of the wheel comes to be obstructed by the rising water of the next tide, there being an interval of about six hours in every tide in which the water contained in the ditches may be expended in working the mill: this is properly what is called a tide mill, and its power or quantity of business to be done thereby on each tide, will depend upon the quantity of water that can be pent up and expended, together with the perpendicular fall that can be given to it; but as both these will be variable in different kinds of tides, that is, of spring and neap, it is proper to observe, that from the gage mark upon the post to the bottom of the mill conduit, there is a fall of seven feet, but that upon the 8th of June last, being two days after the moon's quarter day, and consequently dead of neap, and at a time of the year when the tides ran shortest, the utmost flow of the tide was eighteen inches below the gage mark, and consequently from the surface of high water to the bottom of the mill conduit, there were no more than five feet and a half: And I further observed, that when the water was reduced one foot below the high water mark of this tide, the ditches were in a great measure emptied, very little water remaining except in the little pond contiguous to the mill

mill, from whence it may be concluded, that very little business of any kind can be expected to be done when the tides are in this state. I shall therefore make my computation upon the business that may be expected to be done at such tides as will fill the ditches up to the gage mark, and from the observations I made on view of the ditches, and of the plan of the parish of St. George, furnished for my inspection by Mr. Burrows, and also from observations which I have since got made by Mr. Holmes at my desire and direction, I have good grounds for a computation, the result of which is, that supposing the ditches filled to the gage mark, and the water required to be raised forty-five feet, 500 hogsheads, wine measure, of water, may be raised per tide, and consequently double that quantity in two tides, being a little more than twenty-four hours; but suppose, that at an average, 500 hogsheads be raised per twenty-four hours for the service of that part of the town, this quantity, at the average price we are paid at our works at Deptford and Greenwich, should bring in water rents to the amount of £190 per annum; the principal difficulty that will attend this tide mill as a water work, will be this, there will be about five days every fortnight at the dead of neaps, during which the supply of water will be so trifling that all the principal families will be under the necessity of having a cistern or reservoir, capable of holding five days ordinary consumption of water, for, in regard to extraordinary consumptions, and among the lower class of tenants who cannot be at that expense, as the times will be always known before hand when the supply will be defective, viz. one day before the quarter day of the moon, the quarter day itself, and three days after, they will be led to contrive accordingly.

It is at present impossible to make a proper estimate of the expense, till a proper plan to proceed upon is made out, and the extent of the service known, but to give some idea thereof, in order that its eligibility may be judged of, I suppose that a capital of £1500 will be required to be laid out upon these works, viz. £500 in building a proper engine and repairing the sluice and mill gates; £500 more in making a proper reservoir, for taking in the Thames water as clean as possible, for the engine to raise, and in the erection of a stand pipe, and supposing one mile of five inch pipes to come to, all expenses included, five shillings per yard, this will be £440, but as it is probable, that neither a mile of pipe of so large a bore as five inches will be wanted, nor yet that a mile in length will be sufficient, we may reckon the article of pipes at £500 at least; the attendance and annual repairs may be stated at £80 per annum, and if £20 per annum be set off for the rent of the mill in its present condition, there will then remain £90 per annum, in return for the capital.

In order to judge what value the mill may be of, for the common purpose, I have also computed what its produce might be expected to be in grinding wheat, and making flour, the result is, that when the ditches are filled to the gage mark, it may be expected to grind twelve bushels per tide; but to allow for deficiencies of neap tides, we will rate its performance at sixteen bushels, or two quarters, per twenty-four hours; this, at 2s. 6d. per quarter, will be £91 5s. per annum, and to repair and alter the premises to this effect, will take a capital of at least £200, supposing all the machinery and materials upon the premises, to go along therewith; the miller's wages and repairs of the mill cannot be rated at less than £60 per annum, and if £20 be set off for the rent of the premises as they now are, there will remain only £11 5s. per annum, in return for the capital.

It is impossible to judge with exactness, but the above statements are the most probable that I can form; from whence it appears, that unless it be judged adviseable to go into the scheme of a water work, it is not likely to fetch more than £20 per annum rent, or even so much, unless you can let it to some neighbouring manufacturer in the dying, scouring, fulling, or iron branches, to whom, as a particular and local convenience, it may be worth much more than to be employed in a business, where the mills in the country are upon the same footing in point of situation.

Lastly, I must point out, that from appearance the ditches not only seem a good deal filled up and obstructed, but I apprehend are curtailed in dimensions by the new roads, and new buildings, so that in fact, the reservoir or mill pond of the Pudding mill contains less water than heretofore, and though it is probable that some advantage may be got to the mill by clearing the ditches, yet as this advantage will be purchased by the expense that will probably attend the clearing or getting them cleared, I have contented myself with reckoning upon what is now subsisting.

J. SMEATON.

Newcastle, 16th August, 1775.

P. S. The Falcoln iron foundery in that neighbourhood employ horses in boring and turning cast iron work; it seems therefore to me, that this is a thing that would suit them.

DALRY

DALRY MILLS.

REPORT of JOHN SMEATON, engineer, upon the memorandum of Mr. John Russell, of the 16th July, 1771, concerning his mills, called the Dalry Mills, near to and west of Edinburgh.

ACCORDING to a level taken by Andrew Meikle, there is a fall of twelve feet three inches from the surface of the water at a full head, to the bottom of the new wheel race, and it is probable that nine inches additional head may be gained at a moderate expense, so as to make in the whole thirteen feet of fall. Upon this certainty of twelve feet three inches, and probability of thirteen feet, I would advise an overshot wheel of eleven feet diameter, which, with the construction I propose, will work very well with a head of one foot three inches, and even with one foot, or, occasionally, with nine inches; but if the probability of raising the present full head nine inches is thought great, to give more compass, I would advise the wheel to be ten feet nine inches only.

A water-wheel of this kind should, upon this head and fall, with the water I saw, dispatch at the rate of $2\frac{1}{2}$ bolls of wheat per hour, and five Winchester bushels, supposing half the water taken to the oat mill and snuff mill.

I would propose the overshot wheel to go the same way round as the present intended breast wheel, and from the bottom of the wheel up the breast, to the height of the axle, to work a true curved fall of stone work, and above the axle to rise perpendicular. This part of the work will, therefore, be obliged to be done up anew, by a fresh lining of asler. The great cog wheel not to exceed eight feet diameter, out and out, so that in case the water wheel is eleven feet, the under-side of the cog wheel will be eighteen inches above the bottom of the race, and if ten feet nine inches, then it will be $16\frac{1}{2}$ inches, which I apprehend will be sufficient to keep it clear of the water in ordinary times, and in speats, if made of and geered with oak, it will go wet, as many mills are obliged to do constantly.

If this general idea is approved of, it will be necessary for me to give a design for the water wheel and trough, and shall also send the proper numbers to accompany it; but, if it is resolved to go with the breast wheel of sixteen feet, as now designed, I shall, if required, give the proper numbers to accompany that.

An

An alteration in the oat mill and snuff mill will, undoubtedly, be necessary, in order to allow water to the wheat mill in dry times, as these mills, as they now stand, occupy the whole water; and though no advance of rent can be expected upon these mills, however good and valid they could be made, yet the less water they are made to use, in doing their present business, the more can be spared to the wheat mill, which will proportionably advance its value.

To do this in the most effectual way would, doubtless, be to rebuild the oat mill in the manner I recommend for the wheat mill, with a double motion, and the snuff mill can be driven from the same wheel, as proposed by Mr. Meikle; and were the premises mine, I would certainly do it in this way, as the oat mill and snuff mill would go together with two-thirds of the water they can otherwise be made to do with; but if Mr. Russell thinks this will be launching into too great an expense, it will certainly be a great improvement to place the two wheels to take the water from each other, as they will then both work with the same water; but in this case, when one of them wants to work alone, it will consume the same water as if they both worked, and therefore will greatly diminish the supply that at those times might be taken to the flour mill; and as the race of the lower mill must be sunk, together with all the machinery, which, when moved, will be found to want many repairs, and perhaps several parts new; this will be something towards building a new mill.

The waste of water, when one of the two present mills is at rest, will be prevented by joining the two falls into one wheel, as proposed by Mr. Meikle, but, unless a correspondent alteration is made in the inside, there will be more water consumed in turning the two mills together, than when they take the water from each other, and to sink the wheel and make a correspondent alteration, will again somewhat approach towards a new mill, and, after all, you will be but possessed of an old mill, continually requiring half as much more water as if constructed upon the best principles; that is, in one case you may spare about one half the present water to the wheat mill, in the other case two-thirds, and the difference will be an addition to the neat profit of the undertaking, and you will have your mills all new.

If Mr. Russell will be pleased to fix upon his plan, Mr. Smeaton will endeavour to advise him how to execute it in the best manner, but to draw a scheme for every possible mode of execution, would require more time than Mr. Smeaton can possibly allot to this business.

J. SMEATON.

Edinburgh, 28th August, 1771.

MEMORANDUM

MEMORANDUM for Mr. SMEATON, concerning John Russell's mills, called Dalry Mills.

BY level taken by Andrew Meikle, millwright, this day, he reports, that from the surface of the water, ten inches lower than the back sluice to the bottom of the wheel race of the new intended flour mill, is eleven feet one inch of fall, and when the water is gathered by stopping the sluices of the mill, it rises fourteen inches higher in the dam.

Andrew Meikle has drawn a plan of the intended flour mill. The house is building, but no part of the mill work is cut out. Mr. Smeaton is desired to consider Mr. Meikle's plan, and to make such alterations as he shall think proper.

The snuff mill is let to Nov. 11th, 1773, at £40 per annum, and the oatmeal mill to the same term at £30 per annum; it is not probable that they will let much higher when the lease is out.

The construction of the new flour mill renders it necessary to make some alteration on these two mills. Andrew Meikle proposes to make one water wheel serve both of them. Mr. Smeaton will please to consider, whether this may be right, and if he thinks the proposal right, he will give his directions, whether it is to be done by an overshot wheel or in the common way, and what dimension and construction the wheel should be of.

The difficulties that occur to Mr. Russell in making these alterations are, that the wheel must necessarily be placed so low, that it may create a considerable additional expense by rendering it necessary to take down and rebuild the side walls of the mill next the water.

2dly. Though the present oatmeal mill may possibly admit of sinking the wheel, yet the foundation of the snuff mill, being considerably higher than the oatmeal mill, it may not admit of sinking the machinery within the snuff mill, so as to answer to the machinery of the outer wheel of the oatmeal mill when sunk; if, therefore, any thing can be contrived, so as to prevent the taking down and rebuilding the snuff mill, it will be a considerable advantage.

3dly. Another inconvenience arising from having one outer wheel for both snuff and oatmeal mill is, that the mills cannot be let to different tenants; it is, therefore, to be considered,

considered, whether it be practicable to have two water wheels for these two mills, both in one line after the other? but if, by dividing the fall, this should be inconvenient, the circumstance of letting the mills to different tenants is not to be minded.

Mr. Smeaton will also consider whether the troughs which is the conduit which leads the water from the sluices to the head of the fall, should be built of stone or made of timber, as Mr. Russell will follow his direction as to that matter.

Mr. Smeaton will please to consider the whole, and give such directions, in writing, as he shall think proper, so that Mr. Meikle may execute whatever plan he proposes.

The REPORT of JOHN SMEATON, engineer, upon the construction of Dalry Mills, belonging to Mr. John Russell.

IN case you can make an addition of six or eight inches or thereupon to your present head and fall of twelve feet three inches, your water wheel may be eleven feet diameter, but in case you cannot, and must stand as you now are, it will be prudent to make it no more than ten feet nine inches diameter, but should you happen to get more than six or eight inches head addition, for every inch addition above six, you may add one inch to the diameter of the water wheel above eleven feet.

FOR THE WHEAT MILL.

Water wheel, in diameter,	11 feet.
The main cog wheel,	54 cogs, at 5 inch pitch.
The great lanthorn,	19 do. at do.
The spur wheel,	62 at $3\frac{1}{2}$ inch pitch.
The lanthorn on the spindles,	13 at ditto.
The diameter of the French stones,	4 feet.

N. B. The water wheel is intended to go eight turns per minute, so that Mr. Meikle can suit his barley mill motions accordingly. I apprehend the following will suit.

The main cog wheel,	54 cogs, at 5 inch pitch.
The great lanthorn,	17 do. do.
The spur wheel,	68 do. at $3\frac{1}{4}$ inch pitch.
The lanthorn on the spindles,	11 do.

The

The same motions and a water wheel of a similar construction will answer for the oatmeal mill as for the wheat mill ; but I should advise to put up a pair of stones for grinding oatmeal of about four feet six inches diameter, with lanthorn on the spindle of fifteen, keeping the five feet stones with the thirteen lanthorn for shelling only ; an axis laid oblique to the horizon from the main cog wheel will turn the snuff mill.

As the main geer will be often wet, it will make it wear much longer to have cast-iron rounds in the great lanthorns, particularly of the wheat mill, which will come to the greatest pressure; if they are made smooth by grinding, particularly where the cogs take, they will not destroy the cogs at first. This is frequently done in our best mills in this part of the kingdom.

I apprehend that three dressing mills will be fully sufficient, but the manner of proceeding in making wheat into flour in Scotland is so very different from what is used here, that Mr. Meikle will be better able to advise you upon this head than I can ; it is good not to have more machinery at first than you want, but to make provision for what by experience you will find to wanted.

J. SMEATON.

Austhorpe, Nov. 27th, 1771.

KILNHURST

KILNHURST FORGE HAMMER MILL.

See plate XVII.

Fig. 1. is an elevation of the machinery in front.

Fig. 2. an elevation sideways, shewing the water wheel and conduit.

The following are those parts which are not rendered evident from an inspection of the design: a, is the breast board of the shuttle; b, is a piece of an iron plate nailed on to the nose or edge of the shuttle, to make it deliver the water in a clean sheet.

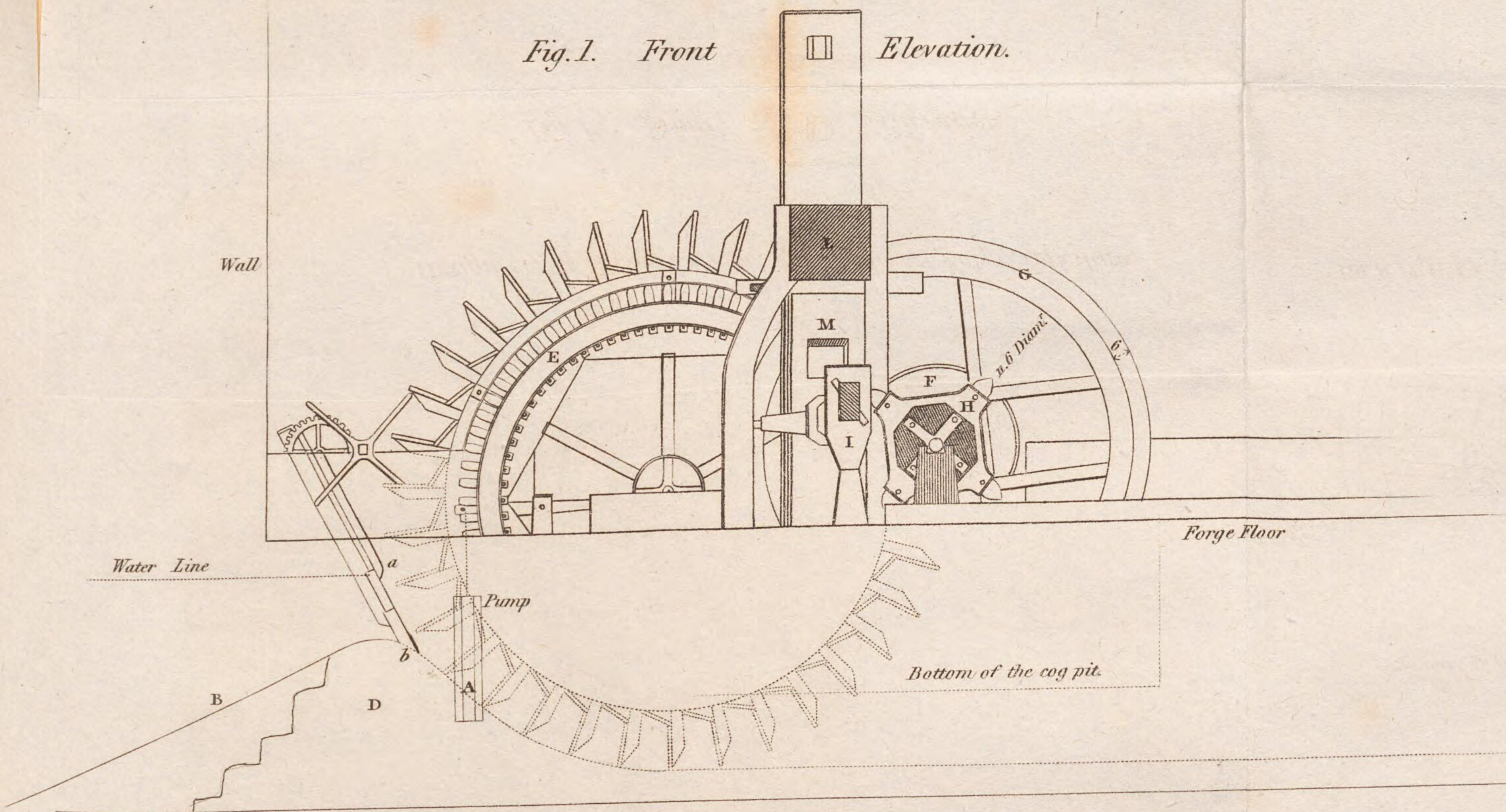
A, is a pump, worked by a tappet in the water wheel axis, to keep the cog pit free from water, when the tail water is above the bottom thereof.

The water wheel is fifteen feet diameter out and out, and six feet wide with thirty-six floats; the water line, when at a full head, is two feet above the crown of the fall D, and five feet ten inches above the bottom of the wheel race; the outside stones both upstream and downstream of the fore bay D, or breast or fall of the wheel, to be jointed with cement of terras, and the inside with good mortar, mixed with forge scales or minion; the slope B is formed by an apron of earth spread on the masonry.

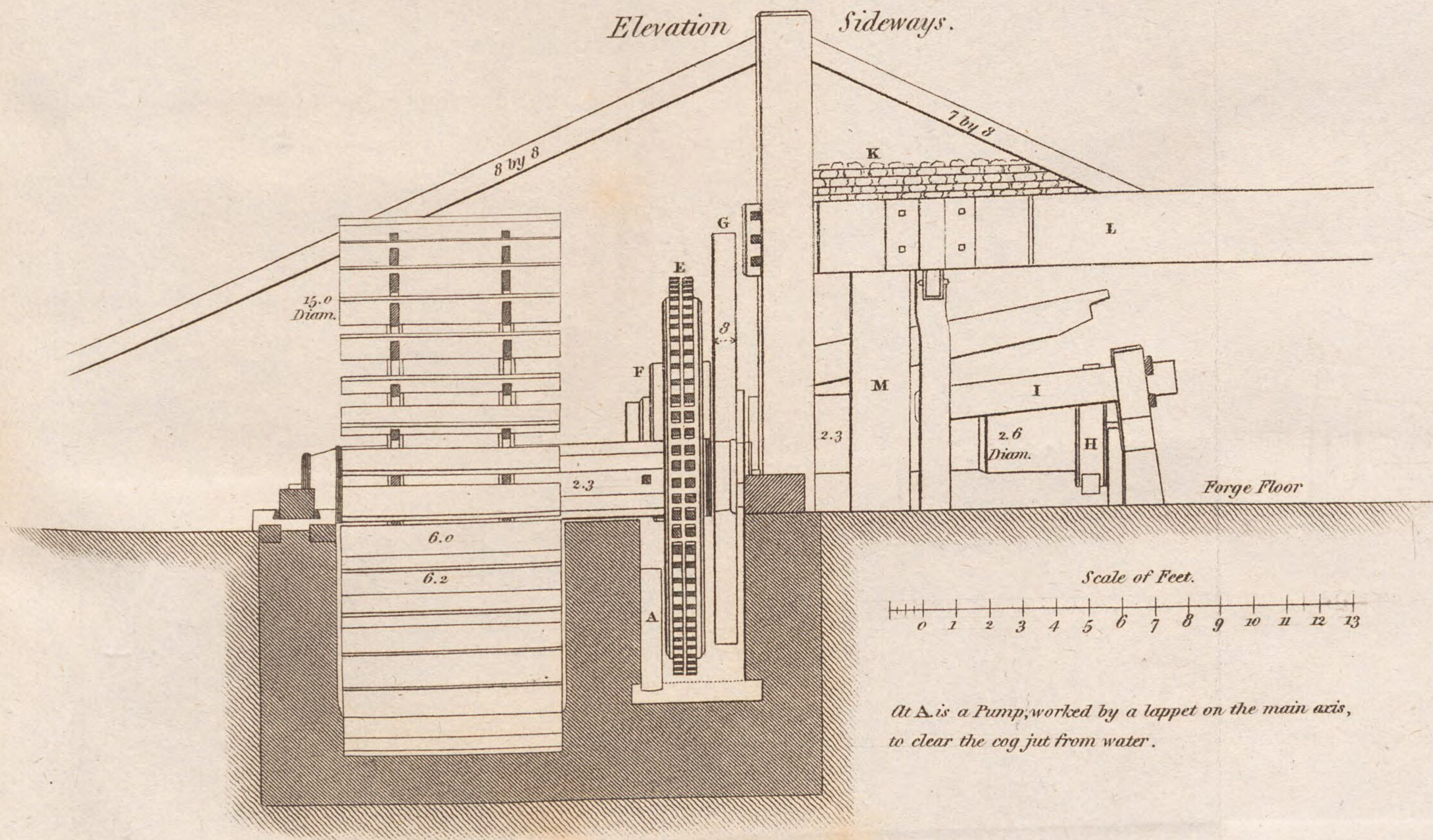
The open wheel E, or the water-wheel shaft within the house, to be ten feet six inches in diameter, with seventy-two cogs, at $5\frac{1}{2}$ inches pitch, and the wallower or trundle F, which it turns, to have twenty-five rounds at the same pitch, and will be 3 feet $7\frac{3}{4}$ inches diameter; the fly wheel G, is to be eleven feet six inches outside diameter, being surrounded by a cast iron ring eight inches by six in section; the iron ring H, with four cogs (describing a circle of four feet eight inches diameter), is to be fixed on the end of the shaft of the fly wheel, for lifting the hammer I; the gudgeon for the end of this shaft is to be cast upon a crop d, fig. 1, the back face of which is to be made one quarter of an inch broader than the fore face, that when the wood is wedged round it will be grasped, and held in like a dovetail, exclusive of the four screws; but if this is not preferred, a common gudgeon may be applied to the same ring.

The

Fig. 1. Front Elevation.



Elevation Sideways.



Scale of Feet.
0 1 2 3 4 5 6 7 8 9 10 11 12 13

At A is a Pump, worked by a lappet on the main axis, to clear the cog pit from water.

Fig.

Fig.

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The rest of the machinery, being the framing or harness for the hammer, is supposed to be subject to the corrections of the forge carpenter, and are only shewn in the design to mark their relative places.

K, are pigs of iron, to serve as a weight upon the drôme beam L, and puppet post M.

THORNTON WATER WHEEL.

See plate XVIII.

EXPLANATION of the design for the water wheel for the upper paper mill at Thornton.

THE water wheel is intended to fit its sweep and sides of the conduit, the same as if it were a breast wheel.

The outside rings and outside of the shrouds are intended to be flush.

If the arms cannot be got curved, as represented, they may be made straight, according to the dotted lines.

a a—Represent straight pieces of hoop iron, about $1\frac{1}{4}$ inch, or $1\frac{1}{2}$ inch broad, nailed on, in order to strengthen and preserve the edge of the bucket boards.

A—Represents one of the two sliding shuttles, where note, that in order to make the same water tight

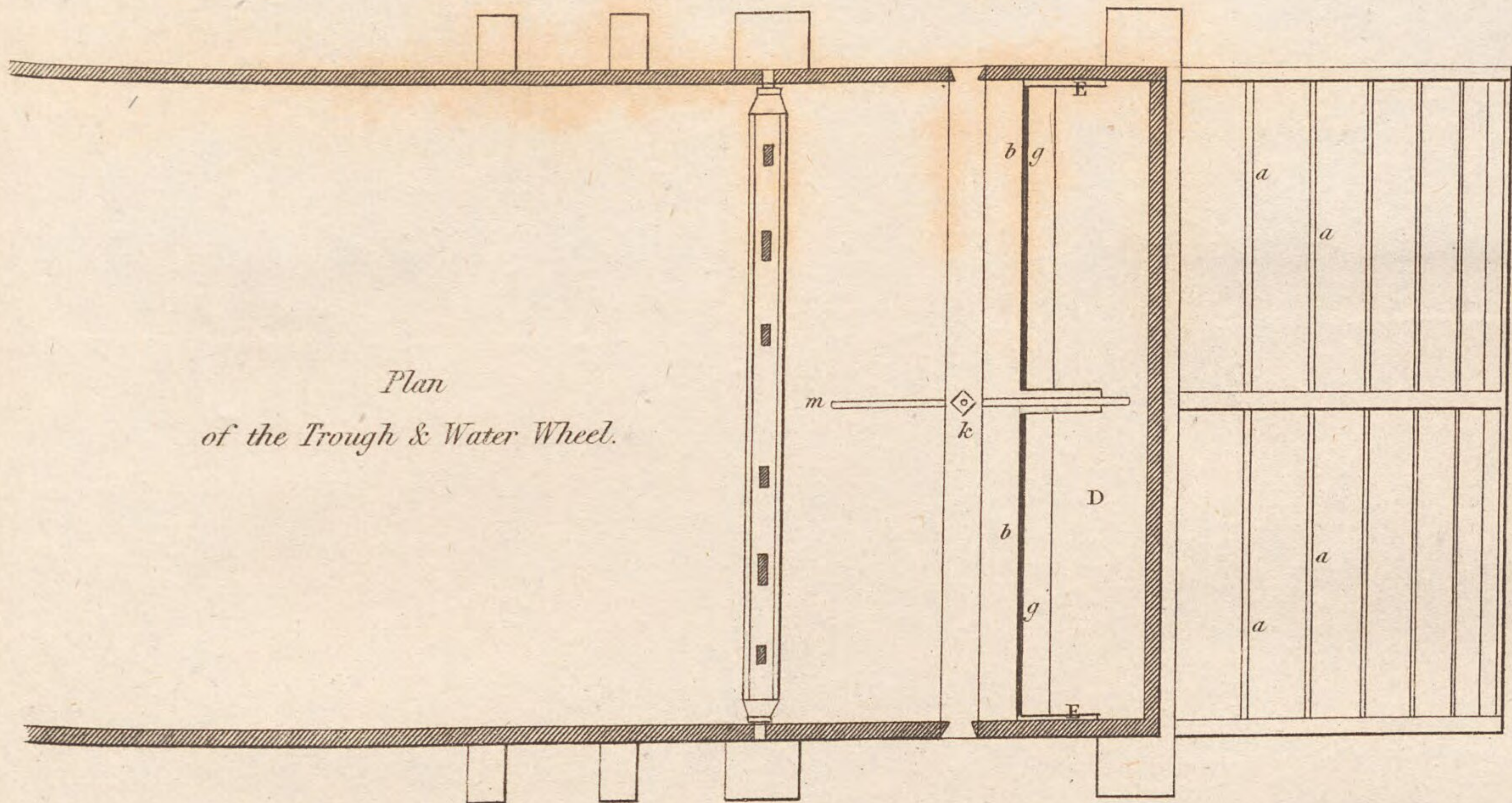
b b—Represent a piece of leather about two or three inches broad, to secure the joint between the shuttle and the bottom of the trough.

E—Represents the end of a piece of leather about $2\frac{1}{2}$ or three inches broad, and of the same thickness with the former, which, being fastened to the tail of the shuttle, slides along with it, in order to keep it upon a parallel.

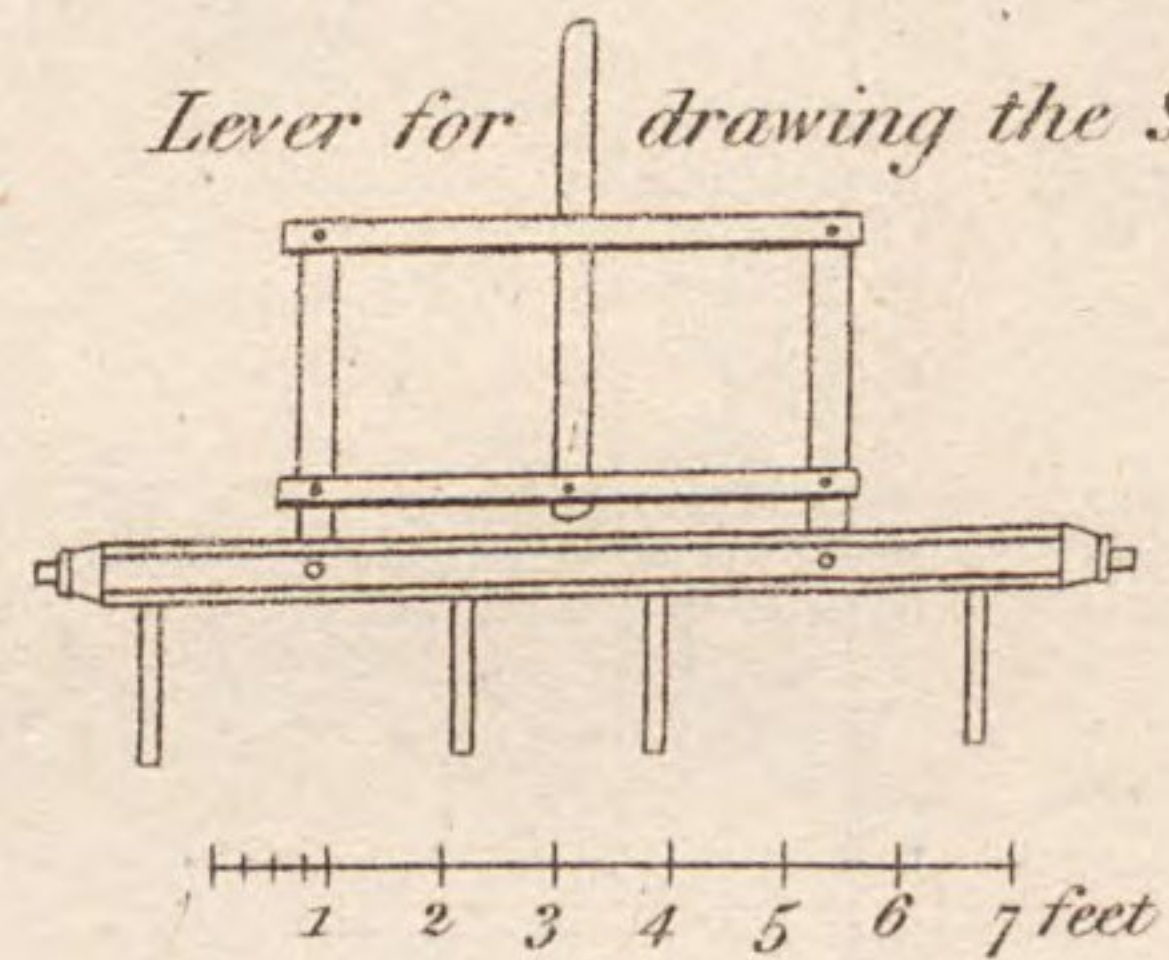
f—Represents the end of a piece of leather fixed to the shuttling forehead of the shuttles, in order to secure the joint between the forehead of the shuttles and the sloping board D; and in order to make it deliver the water fair, the lower part of the leather is intended to fall below the wood about half an inch for the length of the open space between the parts c c, where it will be clear of the leather first described.

g g—Represent an iron plate, which will not only secure the sharp edge of the sloping board D, but by turning $1\frac{1}{4}$ inch of the breadth of the lower part of the plate into an horizontal direction, will make the stream nearer horizontal, and cause the point of the bucket more freely to enter the stream.

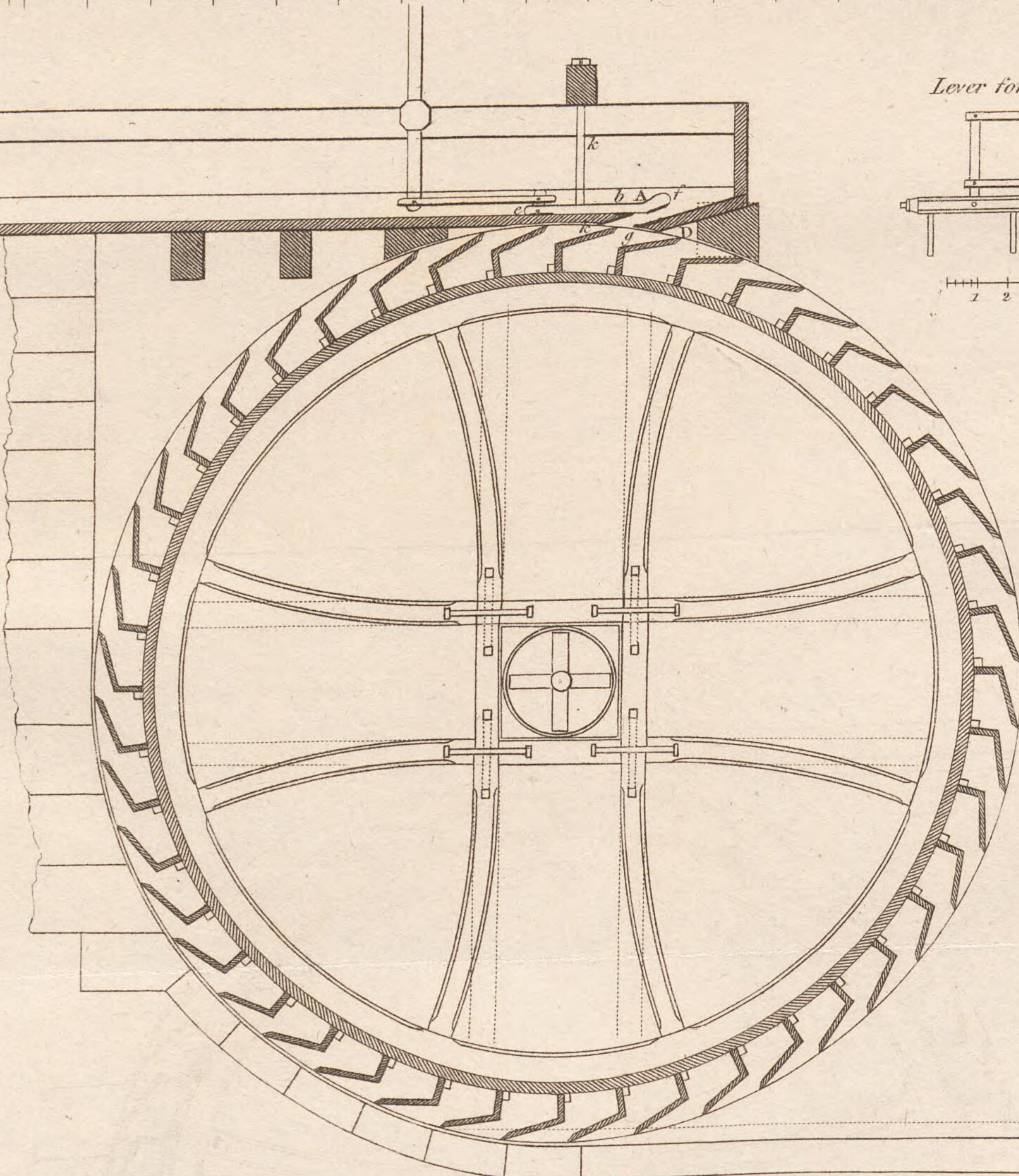
Plan
of the Trough & Water Wheel.



Lever for drawing the Shuttle.



Section of the
Water Wheel,

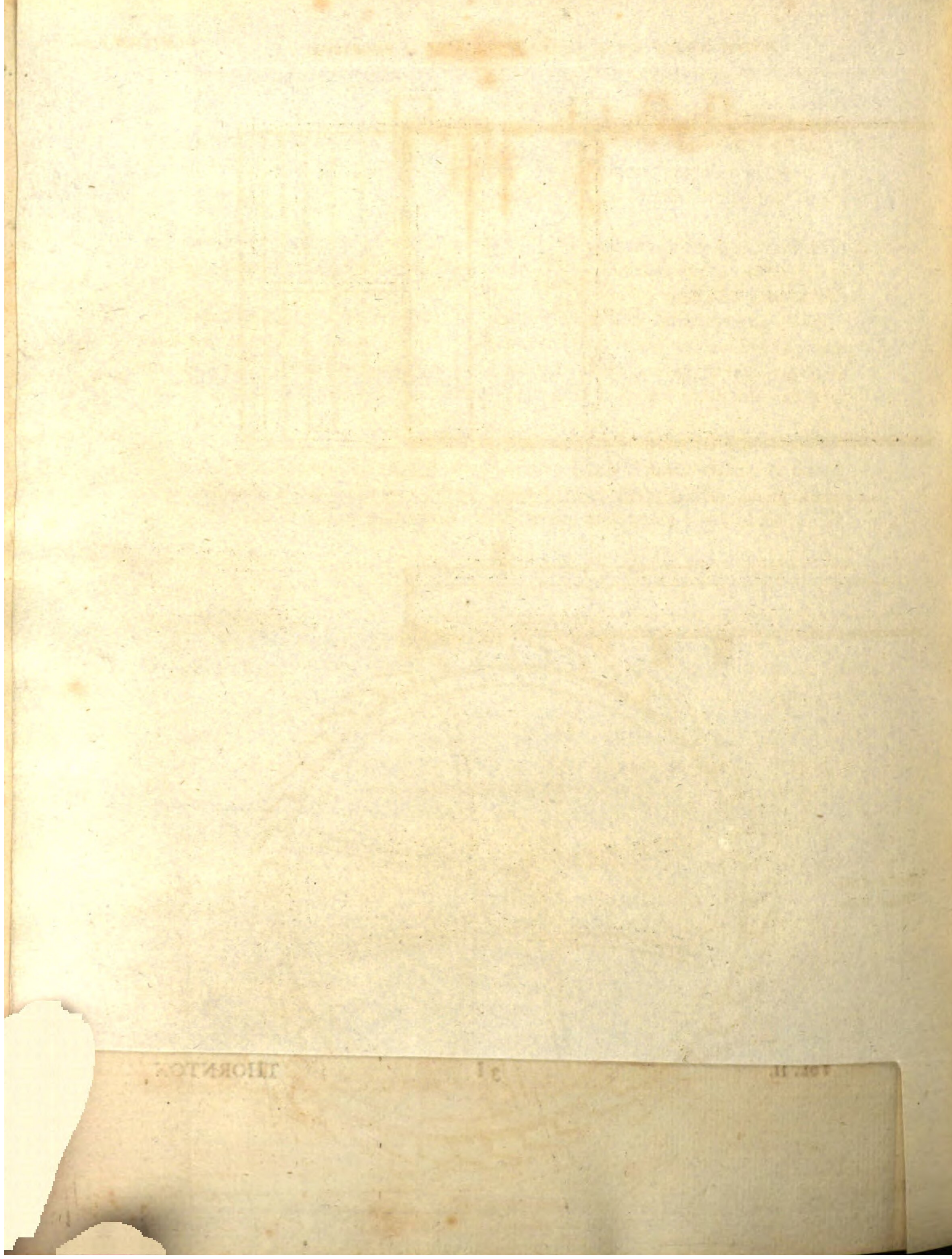


Wheel Race,
Trough & Shuttle.

Designed by J. Smeaton.

Engraved by Wilson Lowry.

London, Published by Longman, Hurst, Rees & Orme, 1810.



h—Represents the end of a piece of leather, to fall or hang down a little below the wood, in order to prevent the water, when going out in a full bore, from following the bottom of the trough.

N. B. Besides the above described, bits of leather should be nailed to the lower side of the parts *c c*, to hang down a very little, to make the stream deliver clean at its ends.

k—Represents an iron bolt going through the bottom of the trough between the two shuttles, in order to prevent the bottom from sagging by the weight of the water thereupon, and to prevent the shuttles from rubbing against the bolt; a small fillet *m*, must be nailed to the bottom to keep them separate.

Each shuttle is drawn by two parts, to keep their motion parallel, and that one shuttle may not draw before the other, or one side of the same shuttle before the other, by the twisting of the roll, springing of the leavers, &c. it is proposed to be framed according to the upright thereof, which is drawn to a lesser scale.

WINLATON BLADE MILL.

See plate XIX.

THE general design for the blade mill at Winlaton is as follows:

The water wheel is to be overshot, eight feet wide, and thirteen feet high, and its bottom even with the surface of the adjacent river. It is intended to receive its water from the head, in the same direction as at present, by a kind of mechanism, which is particularly described hereafter, the water is made to shoot backward, and to turn the wheel round the same way as at present.

The house is supposed to stand as at present, or, if pulled down, to be erected of such dimensions as are best adapted for its purpose; each tumbling axis may be made longer or shorter, or to carry three strap wheels, if required.

As the water wheel axis, according to the above dimensions, will stand about four feet eight inches lower than it now does, if worked by a single gear, as at present, it would be necessary to lower the floor of the house and the grindstones in the same measure, which might be inconvenient on account of the floods. By introducing the upright axis, the strap wheels will be about one foot higher than they now are; and, if productive of any advantage, may be made still higher, by placing the horizontal wheel higher on the upright axis.

Though the machinery will be somewhat more expensive on account of a double motion, yet it will be more lasting, as it will go more smoothly, and with less friction.

This mill will go with at least half, if not one-third, of the water now used to do the same business, and will perform with full effect, till the water is sunk about sixteen inches under head; and then, if wanted by the tilt mills or forges, the grinding mill must stop.

The wheel, though laid so much lower, will in times of flood perform nearly as long as the present wheel; that is, it will perform with about four feet tail water, what would make about one foot in the present wheel; and, as the floods continue but a short time, it would be wrong to lose an essential advantage for the sake of a few hours in the year.

As

As all the designs are drawn true to their respective scales, they will in a great measure explain themselves.

Fig. 1, is an elevation of the machinery for Winlaton Blade mill, with a section of the wheel and trough, and upright of the lever for drawing the shuttle.

Fig. 2, is a front elevation of the machinery seen from within the house : the design sufficiently explains itself, and the following are the proportions :

The water wheel A A is thirteen feet diameter out and out, and has forty buckets ; the water line, when at a full head, is supposed to be two feet four inches above the top of the wheel.

The pit wheel B, 72 cogs, at 5 inches pitch.

The great lanthorn C, 25 at 5 inches.

The horizontal wheel D, 60 at 4 inches.

The small lanthorn F F, 17 at ditto.

The wheels or runs I, I, I, I, which carry the straps for turning the grindstones, to be five feet diameter, and the length of the axis G, H, upon which they are fixed, to be adapted in length to the width of the house, and the wheels are to be set at such distances upon them as are most convenient for the disposition of the grindstones.

K is a square head upon the upper gudgeon of the vertical shaft, by means of which works may be turned in the upper room ; n n, shew the lower cog pit for the main cog wheel, and o p, the upper cog pit or platform for the headstock M, and rider N, which are to be bolted together, to support the gudgeons of the water wheel and the upright axis.

The brasses for the gudgeons of the two lanthorns F F, must be rather deeper than the half circle, especially towards the side that the drift of the mill tends to.

SIR L. PILKINGTON'S FLOUR MILL.

Plate XX, fig. 1, is a plan of the Hirft for Wakefield flour mill.

Fig. 2, is an elevation, and fig. 3, a separate plan of the bridges and brayer for supporting the spindle foot: the design sufficiently explains itself, to be framed in a system of triangles, which are well known to be the strongest figures possible, and do not depend upon any mortising, because the angles, if united by bolts, so that they cannot separate, will be far stiffer than any mortising or cramping can make a square frame. A B C are three beams, forming the upper frame of the hirft, and D, fig. 2, is the edge of a similar triangle, which lies upon the mill floor, and supports the former by the upright E E, and cross braces; F F, fig. 1, are beams framed across the angles of the great triangle A B C, forming smaller triangles, upon which the stones G G are laid; the gudgeon of the great spur wheel I, is supported in a bearing screwed to the beam H; the bridges and brayers are supported on three points, by mortises in the upright timbers E E, and are adjustable at one joint by a screw which bears the weight of the stone; fig. 3, shews this plainly, and also the wedges which adjust the position of the spindle foot. The proportions of the mill are as follows:

The water wheel twenty feet diameter; the difference between the head and fall eight feet at a full head; and then the water stands two feet deep, over the crown or fall; the wheel has thirty-six floats, and is seven feet wide.

The great pit wheel eleven feet diameter, eighty-four cogs.

The great lanthorn, three feet six inches diameter, twenty-four cogs.

The wheels are in the ground floor: the upright shaft goes through the first floor, and turns the dressing machines in the second floor, where the hirft is, it carries

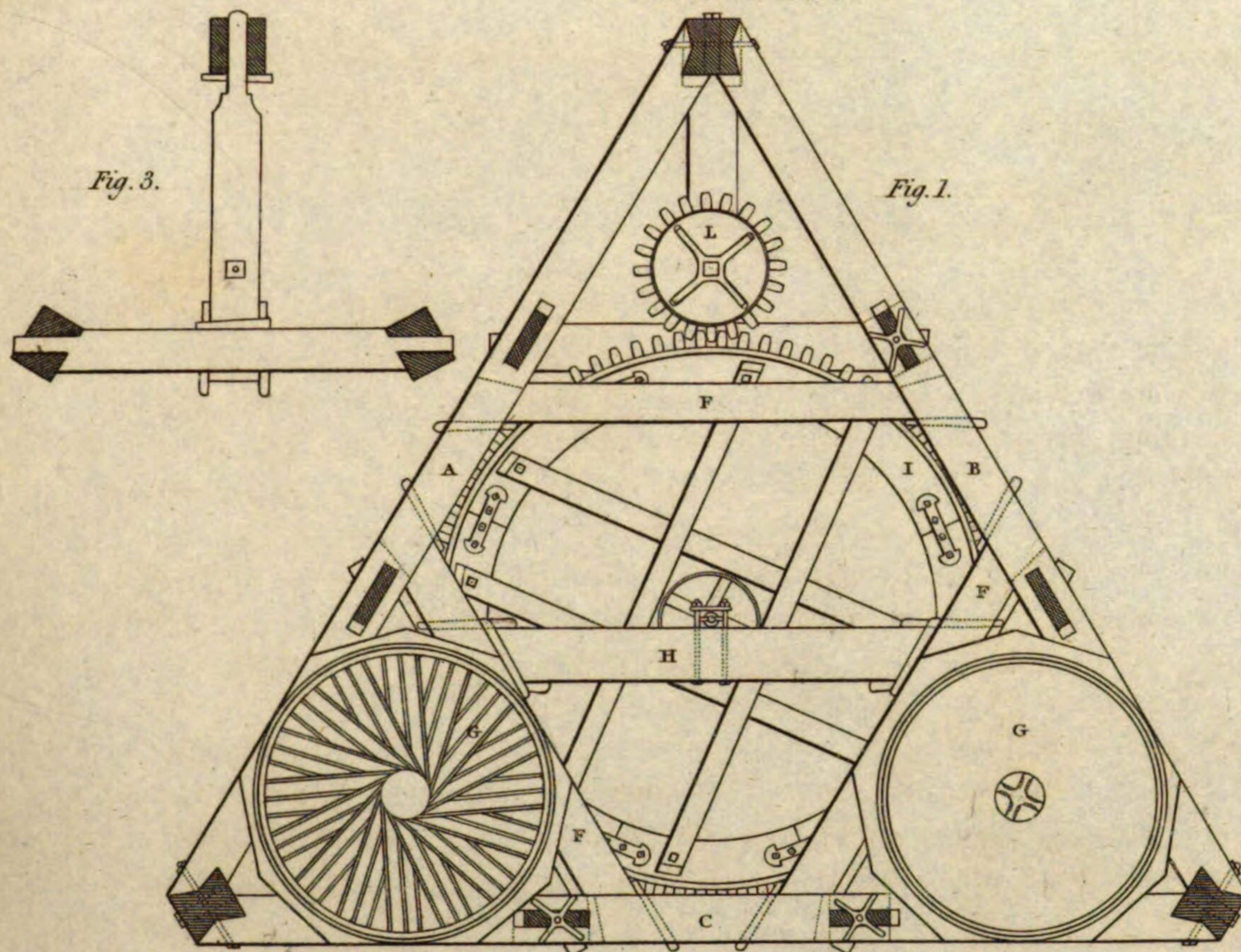
The spur wheel I, eight feet diameter, eighty-four cogs.

The pinions L, one foot eleven inches diameter, and twenty cogs; the stones are four feet diameter.

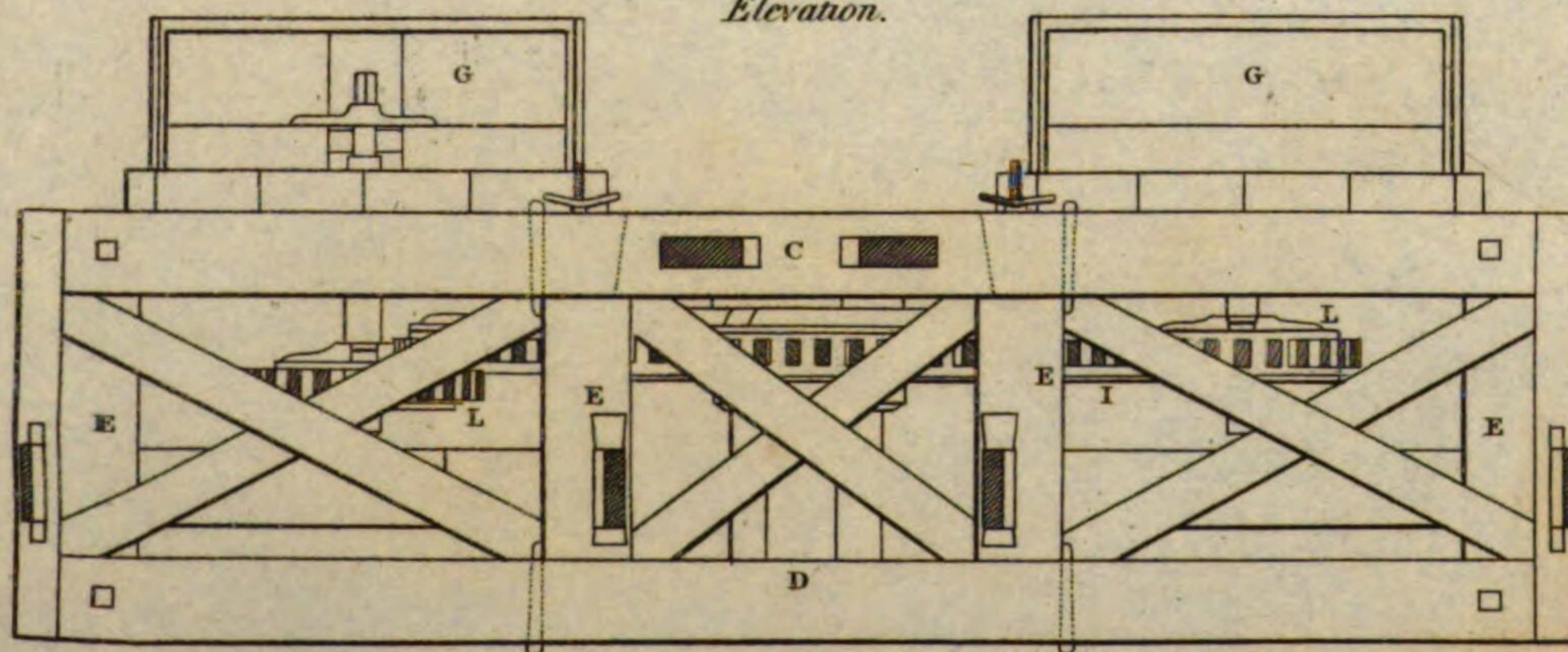
EXPLANATION

*Design for a FLOUR MILL, erected at Wakefield Yorkshire,
for Sir Lionel Pilkington Bart. 1754.*

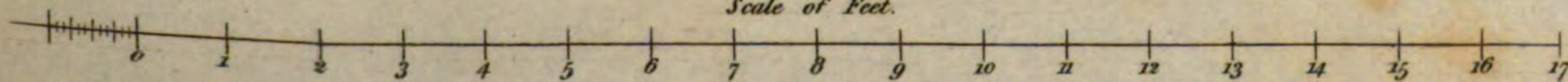
Plan of the Hirst.



*Fig. 2.
Elevation.*



Scale of Feet.

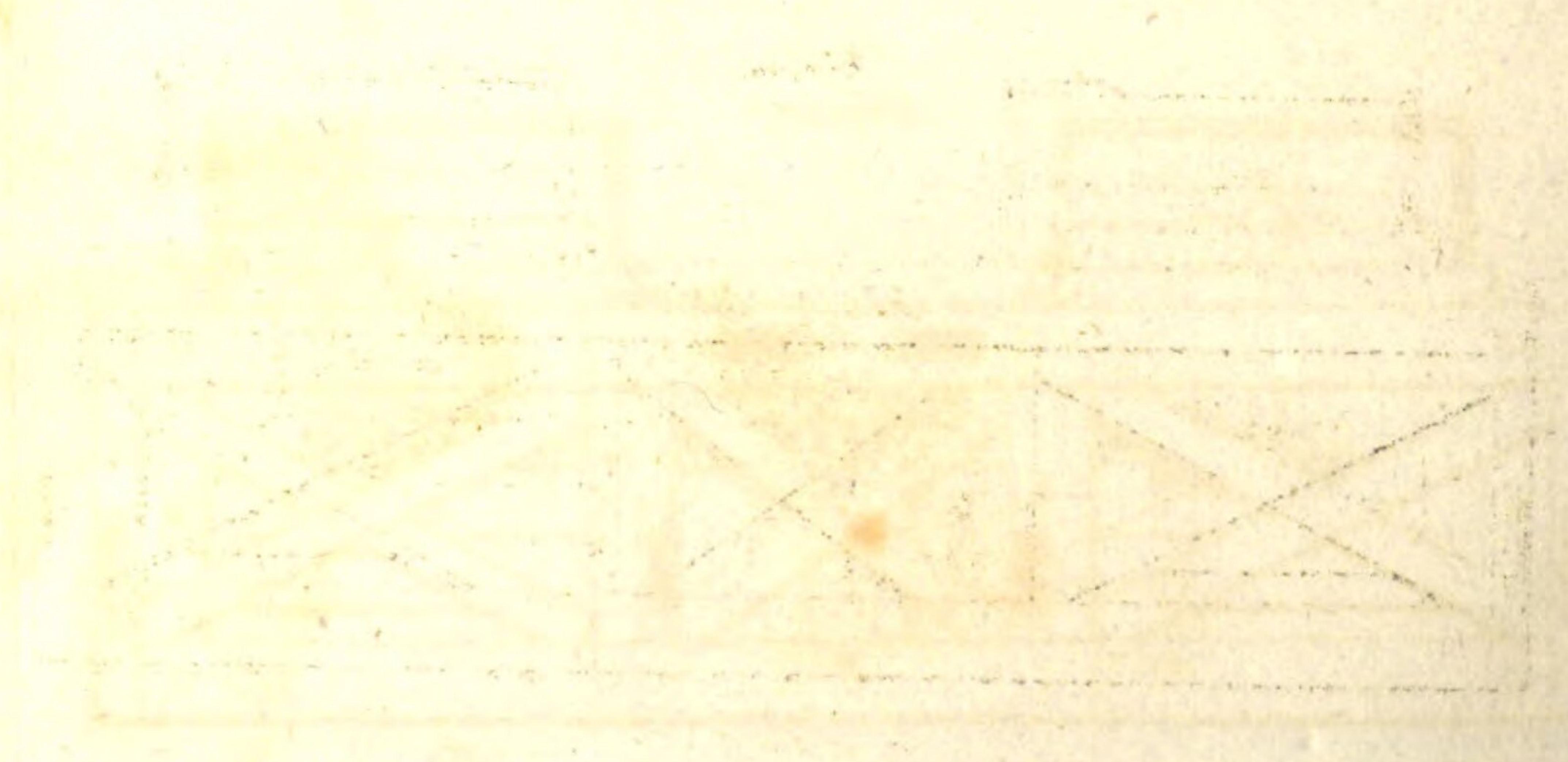
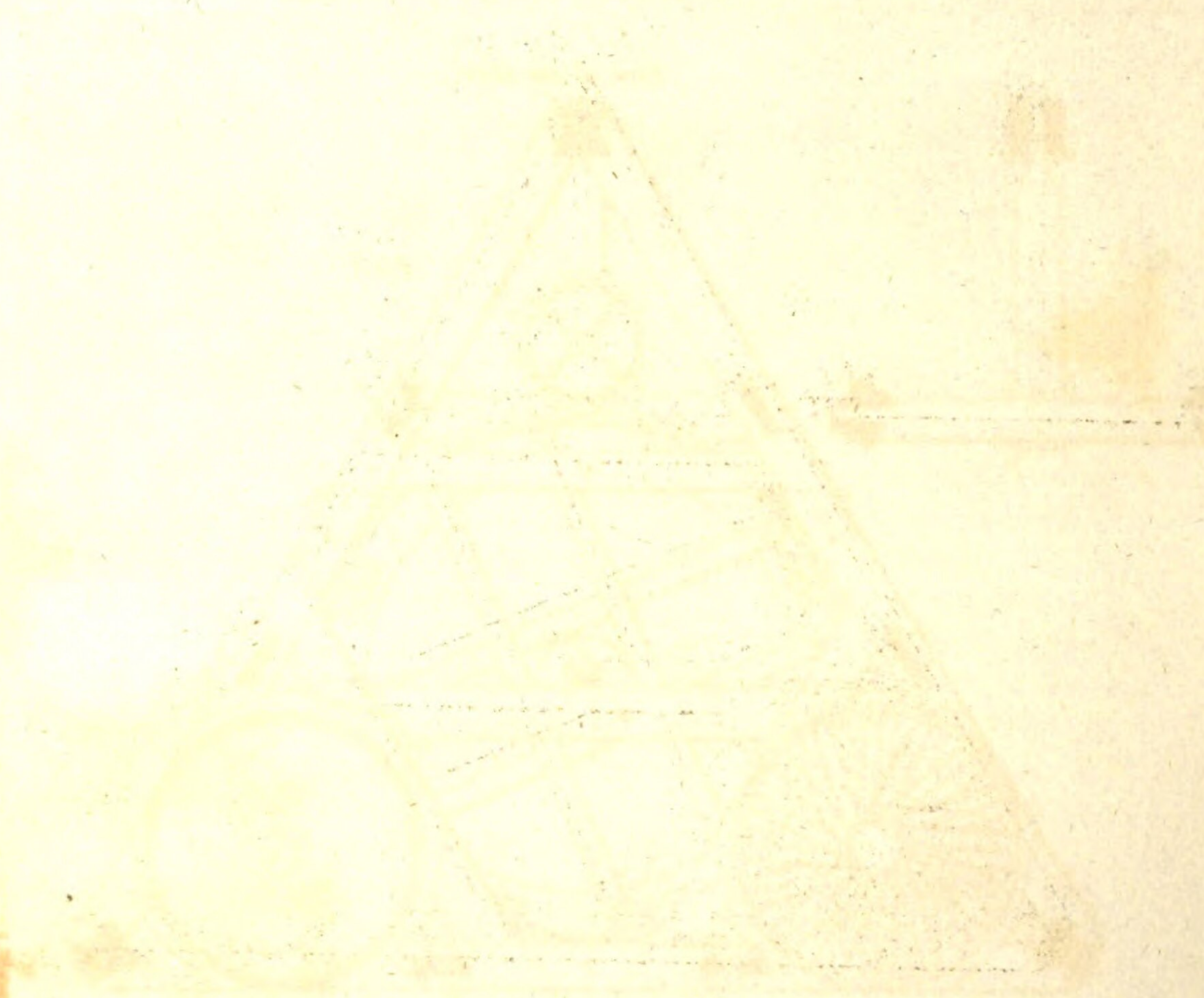


Designed by J. Smeaton.

London. Published by Longman, Hurst, Rees & Orme, 1810.

Lowry sculp.

J. Faray delin.



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WATER ENGINE, Erected for Lord Irwin at Temple Newsham, Yorkshire.

Fig. 3.

Upright sideways
of the
Sliding Valve.

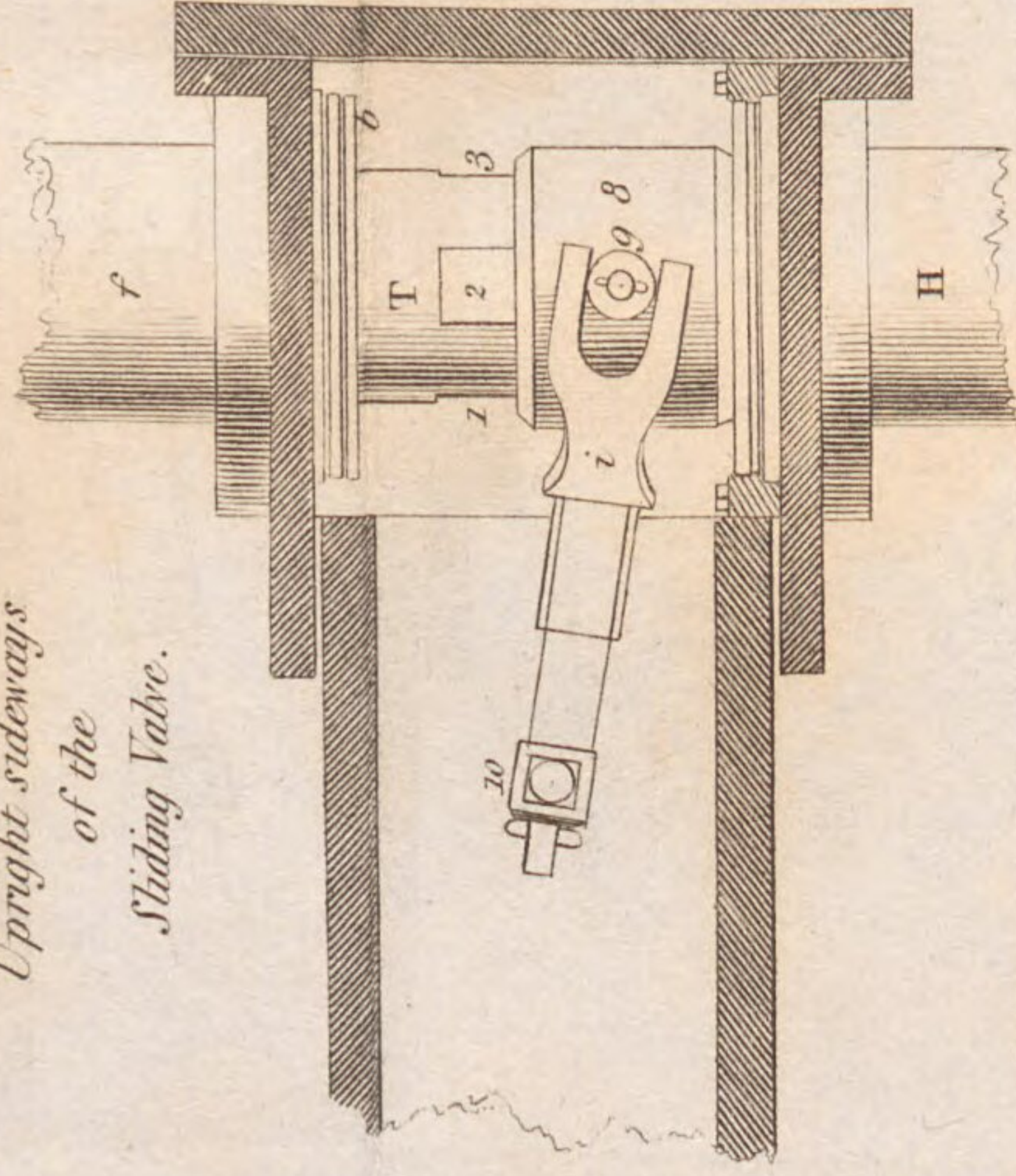
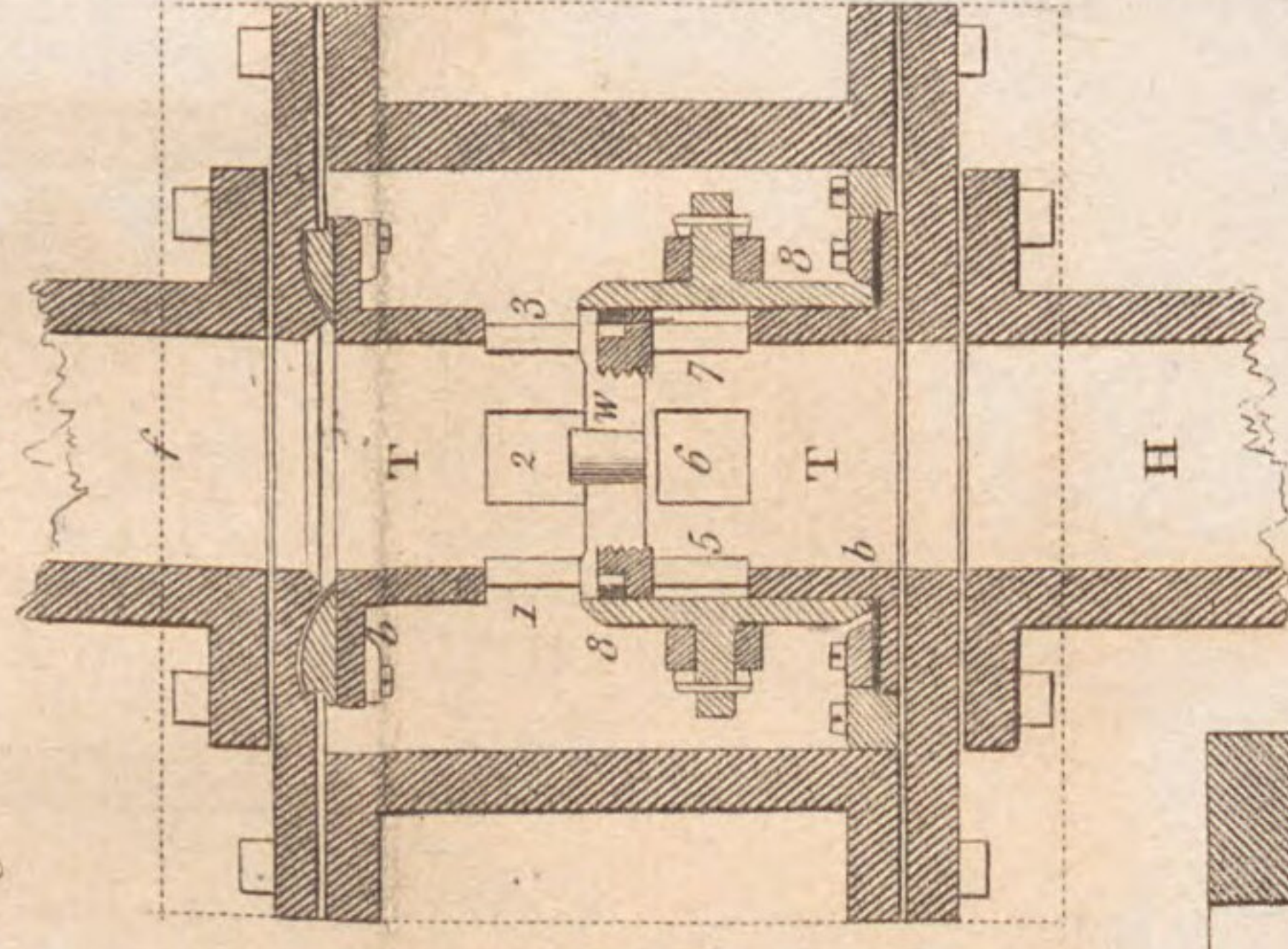


Fig. 4.

Section,
in Front.



Plan. Fig. 5.

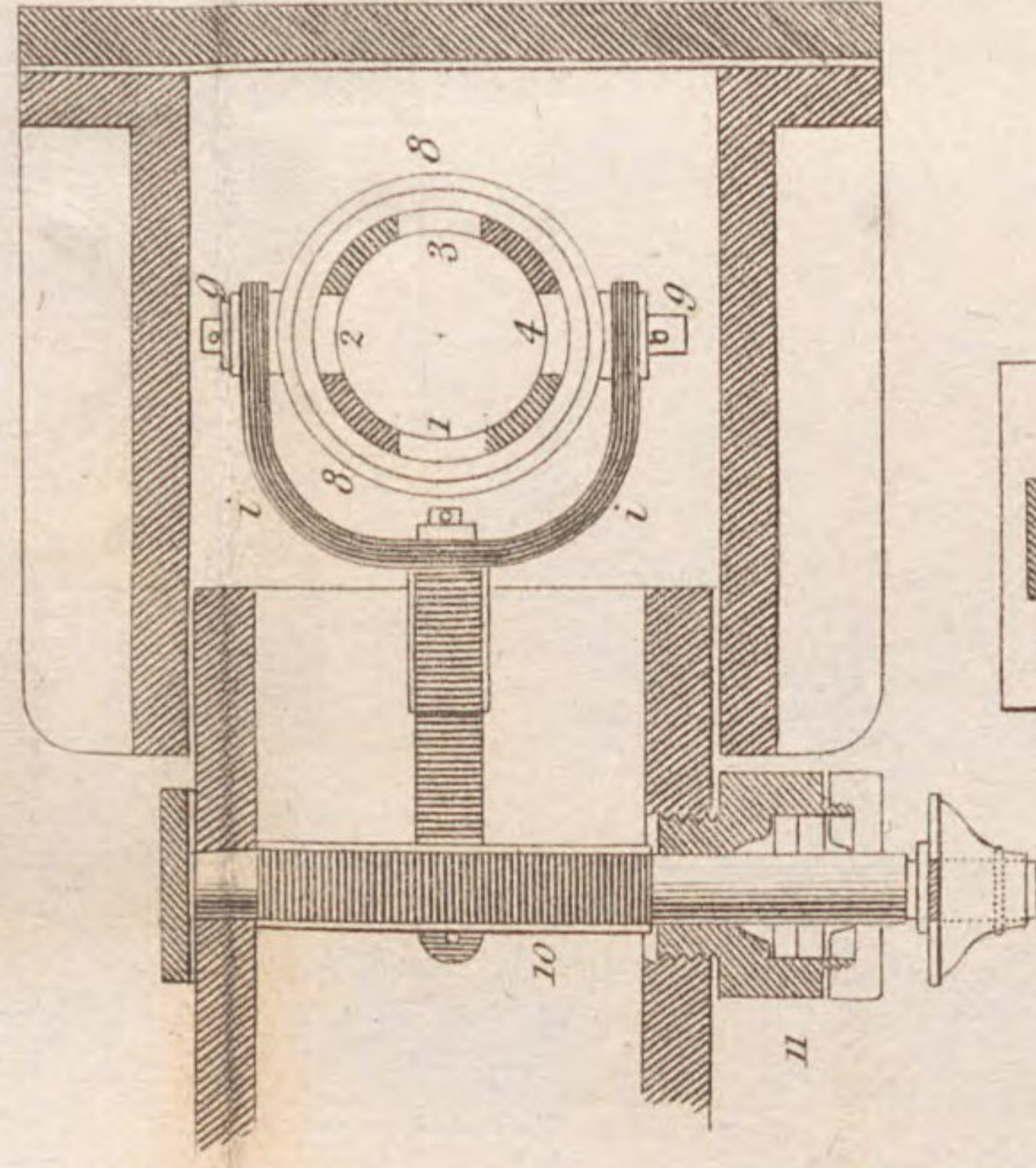


Fig. 1.

Side Elevation.

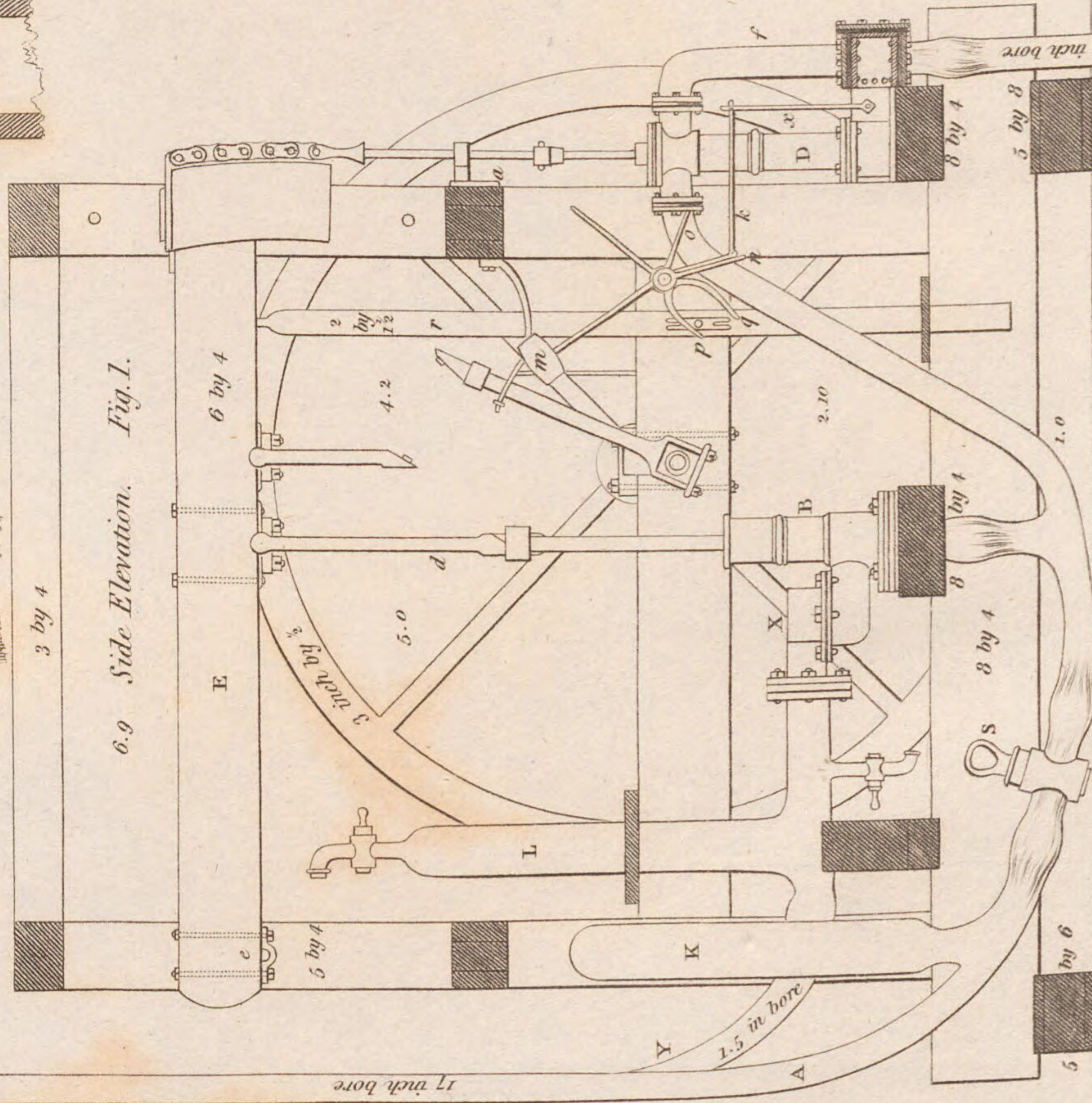
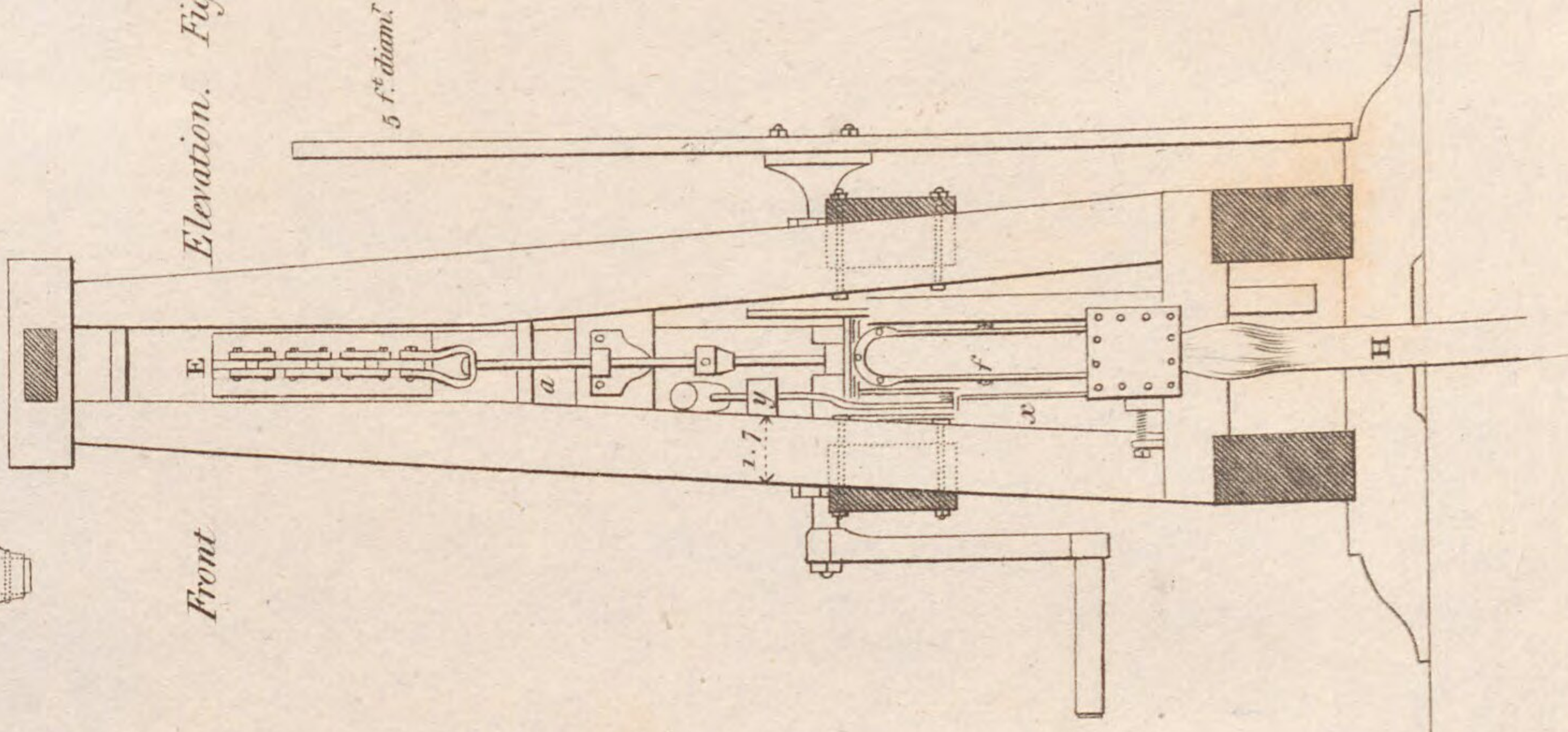


Fig. 2.

Front



Scale of Feet.

Inches.

J. Farey delin.

Designed by J. Smeaton 1769.

London, Published by Longman, Hurst, Rees & Orme, 1810.

Engraved by Wilson Lowry.

EXPLANATION of the designs for a water engine erected for Lord Irwin,
at Temple Newsham, in 1770.

See plate XXI.

Figs. 1 and 2, are elevations of the whole engine, and figs. 3, 4, and 5, enlarged sections of the sliding valve, which regulates the admission of the water into the working cylinder, at proper intervals, to cause the motion.

The pipe A, which supplies the engine with water, is one-seventh of an inch bore, the perpendicular descent from the mouth, or entry at the spring of supply, is fifty-four feet, and the length 400 feet; the water is conveyed from the engine by a pipe H, which has a fall or descent of fifteen feet from the engine to the surface of the water in the pit or well into which it delivers, and has a stop cock, which regulates the discharge of the water. This descending column of sixty-feet of water is employed in working a pump, which throws back part of the water to a reservoir by a pipe Y of ascent, about 900 feet in length, and one-fifth of an inch bore; the delivery of this pipe at the top of the reservoir is eighty feet above the engine, consequently, twenty-six feet above the level of the head or spring of supply. The pipe A conducts the water to the pump B by one branch, and to the top of the cylinder D, which works the engine, by the other. The cylinder D is of brass, truly bored, and furnished with a solid piston, whose rod passes through a close stuffing box in the cylinder lid where leather is packed round it so closely, that no water can leak by it; the upper end of the piston rod is keyed into a small box, which connects it with an iron rod a, sliding through a guide, to make it more steadily; E is the working beam, moving round a centre at e; it has an arch head at the outer end, which is a segment of a circle struck from the centre e; the arch receives a chain by which the piston rod is suspended, and therefore has a vertical motion; d is the pump rod, jointed to the beam, and moving up and down with it; the forcer of the pump B is fixed to it at the lower end; f is a pipe, which forms a communication between the top and bottom of the cylinder, it leads down into a chest, upon which the cylinder is placed, and to which it is open at bottom; the chest is composed of plates screwed together, as shewn by the sections figs. 3, 4, and 5, which also explain the construction of the sliding valve contained within the chest; in these figures T is a short cylindrical pipe fixed across within this chest, and communicating with the pipe f at top, and the pipe H
(which

(which conveys the water away from the engine) at bottom; this short pipe has a water-tight division, W, fig. 4, in the middle of it, so that there is no direct passage through it from f to H, but there are four square holes 1, 2, 3, 4, made in the pipe, at equal distances round it, above and also below the division, as shewn at 5, 6, 7, fig. 4; a cylinder or tube of brass 8, 8, is fitted upon the cylindric pipe, and slides up and down upon it, being packed with leather round the edges of the middle partition near 1 and 3, fig. 4, that no water may escape between the two cylinders; the sliding cylinder 8, is just half the length of the other, and when it is pushed down, as in the figures, it covers and stops the four holes 5, 6, 7, in the pipe T, which are below the division W, and opens the four holes 1, 2, 3, above the division, allowing a passage from the pipe f, to the bottom of the cylinder D, fig. 1; on the contrary, when the slider is pushed up, the upper holes 1, 2, 3, are closed, and the lower ones 5, 6, 7, opened, making a passage from the cylinder bottom into H; the sliding valve 8, besides the leather packing, which surrounds the partition W, has leather placed at the top and bottom of the fixed cylinder T, at b b, and the ends of the slider are pressed upon these leathers to make a tight joint when up or down, but the cylinder fits as tight as it can be made; independent of these leathers, the sliding valve has a pin 9, projecting from each side of it, which are included between clefts made at the end of a forked lever i i, moveable on an axis 10, which passes through the side of the chest in a collar of leather 11, fig. 5, and has a long lever x, figs. 1 and 2, fastened upon it. By moving the upper end of this lever towards the engine, the sliding valve will be raised up, and by moving it in a contrary direction the valve will be pushed down; k is a small iron rod, jointed to the upper end of the long lever by one of its ends, and the other is suspended by hooks from a spindle, turning upon pivots supported by the framing; this spindle has several levers upon it similar to the working geer of a steam engine, as follows: m n o is a three armed lever, the arm m has a weight at the end, and is called the tumbling bob; n and o are two other arms, made in the same piece with m, these two latter arms strike against a pin fixed across in the end of the rod k, which is forked to admit the pin, and the arms n o act within the fork; p and q are two crooked levers, by which the spindle is moved, as handles; these levers are struck by pins fixed in a wooden rod r, which is jointed to the working beam, and moves up and down with it; y, fig. 2, is a piece of wood fixed to the upright beam of the frame, having pins projecting from it, which catch the tumbling bob m, and prevents its moving too far; S, is a stop cock in the main pipe, which regulates the quantity of water coming to the engine, and, consequently, the velocity with which the engine will work.

To

To describe the operation of the engine, suppose every thing to be in the position of the figures, and the pipes, cylinder, and pump full of water, the sliding valve is down in the position of fig. 3, and therefore forms a communication from the top to the bottom of the cylinder; in this state, the pressure of the descending column of fifty-four feet of water is equal upon both sides of the piston of the cylinder, and therefore has no operation either way, the communication with the pipe H being stopped, so that the water cannot escape through it; but the pressure operates upon the lower surface of the forcer d of the pump rising freely through the lower valve; this pressure being unbalanced, raises up the working beam, and with it, the piston of the cylinder, and the rod r; this, as before mentioned, has pins in it, one of which is seen in fig. 1, to be just meeting the arm or handle p, which it raises, lifting the tumbling bob m, and turning the axis with all its levers, when the engine arrives at the top of the stroke, the tumbling bob passes the vertical point, and falls down on the other side of the centre; the arm o now strikes the cross pin in the end of the rod k, and by drawing it, moves the lever x, and lifts up the sliding valve; this closes the communication between the top and bottom of the cylinder, and opens a passage to the pipe H, permitting the water to pass through the pipe into the well, and thus get away from the engine, removing the pressure of fifty-four feet from beneath the piston, though leaving it still acting at top of the piston, and adding to it the twelve feet from the engine to the bottom of the well, in consequence of this column being suspended in the pipe H; this unbalanced pressure causes the piston to descend, bringing down the end of the beam and pump rod d with it; the valve in the bottom of the pump now shuts, and the water in the pump being pressed by the piston, opens the other valve at X, and goes up the pipe Y, to the reservoir, lifting a column of water of eighty feet.

When the engine gets to the middle of its stroke, a pin in the other side of the wooden rod r, and therefore not seen, takes the lever q, and forces it down, raising the tumbling bob m, at the same time; by the time the piston arrives at the bottom of the cylinder, the tumbling bob is brought past the vertical position, and suddenly oversets by its own weight into the position of fig. 1; the lever n, now runs against the pin across the end of the rod k, and shoves it from the engine, moving the long lever x, of the sliding valve, and the short lever i, fig. 3, down just in the position of the drawings; this closes the four lower holes in the fixed cylinder, and prevents the water going down the pipe H, and at the same instant opens the four upper holes, forming a communication between the top and bottom of the cylinder. The pressure of sixty-six feet, which caused the piston to descend, is now re-

moved, or rather balanced by causing it to act equal beneath the piston, and the column of water of fifty-four feet coming down the pipe A, forces open the lower valve of the pump (the valve at X closing and taking the bearing of the column of eighty feet), presses the under side of the pump bucket, and raises it up, as before described, moving the beam and piston with it, there now being an equal pressure, both above and below the piston, it will be moved up easily. When the piston arrives at the middle of its stroke the preceding operations are repeated, the pin in the rod r takes the lever p, and rises with it till it arrives at the top of its stroke, when it again passes the vertical position, and instantly falls over into the position first described; the lever o, taking the end of the rod k, and pushing it towards the engine, raises the sliding valve, opens the passage to the pipe H, and the whole column of sixty-six feet now presses upon the piston, and forces it down as before described, overcoming a column of eighty feet upon the pump, though the diameter of the pump is larger than that of the cylinder; this happens from the chain of the piston acting upon a much longer lever than the pump; K and L are two air vessels upon the pipes A and Y.

The proportions of the cylinder, pump, &c. are as below.

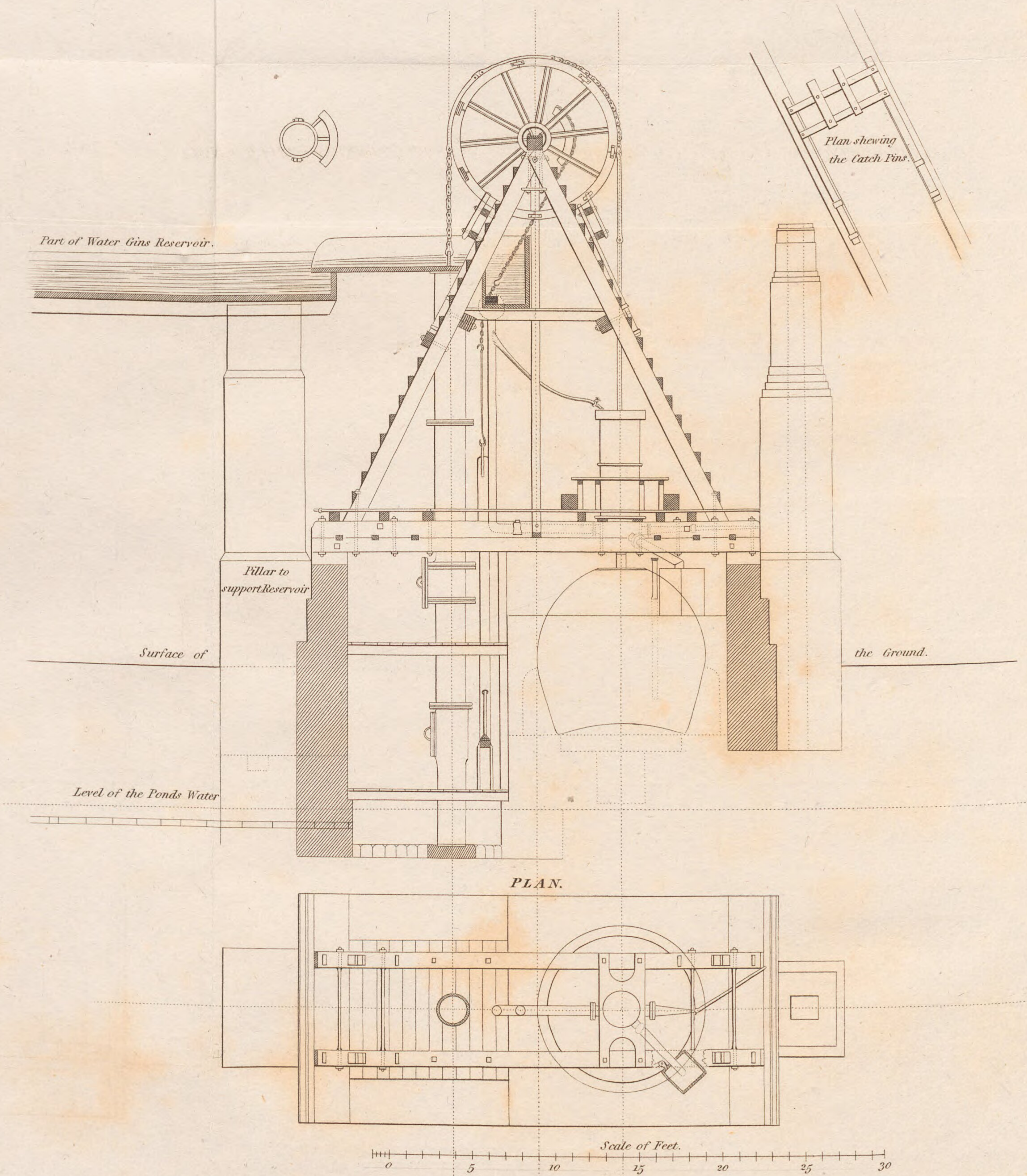
	Ft.	In.
The diameter of the working cylinder,	2	2
The length of its stroke,	10	0
Distance from the centre of motion e, or radius of the lever it actuates	6	0
Perpendicular height of the column of water which presses upon the piston of the cylinder		
when descending 54 + 12,	66	0
Diameter of the pump barrel,	0	3
Length of its stroke,	5	1
Distance of the pump from the centre of motion, or length of lever which works it,	30	6
Perpendicular height of the column of water pressing upon the forcer of the pump to raise it,	54	0
Ditto, raised by the pump,	80	0
Difference, which is the height to which the pump actually raises the water above its source,	26	0

1777.

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ELEVATION & PLAN of a FIRE ENGINE, for raising Water for the WATER COAL GIN, at the Prosperous Pit, LONG BENTON COLLIERY.



J. Farey delin.^t

Designed by J. Smeaton 1777.

Engraved by Wilson Lowry.

London, Published by Longman, Hurst, Rees & Orme, 1810.

LONG BENTON ENGINE.

To Mr. Walton,

Dear Sir,

Buxton, 2d July, 1777.

I NOW proceed to point out such things in the designs for the fire engine and water gin as may most stand in need of explanation, and first with respect to the elevation of the fire engine, you will perceive that I propose that the hand geer for working the engine, shall be down nearly upon the same level with and abreast of the fire door, so that the person that feeds the fire can hand the engine without going up ladders or steps; the particular method of communicating the hand geer with the regulator and injection cock I shall fully explain by a particular draft, and shall send you also a draft for the regulator, which, for this small engine, will be best wholly of brass. The iron injection pipe, cast with the cylinder's bottom, I propose to make really a part of the injection pipe, and to make the communication between the iron pipe and injection pipe by a short pipe of wood, with a brass cap driven into it.

The upper stage is intended to support the injection cistern, which takes its water from, and fills to the same height as the surface of the water in the lander trough, all that is not taken for injection going upon the wheel. I propose a common lead pump occasionally to fill the injection cistern till the water is delivered at the main pump head; but this cistern should be lined with lead, to avoid all leakages, and to give liberty to the motion that the lander trough will have upon the great pump without affecting the injection cistern; I propose the communication to be made by means of a leather pipe to go through both, and to be turned and nailed flanch ways upon the inside of both; also the joint to be made good between the lander trough and the reservoir of the gin by a strip of leather nailed to both; the man that works the common pump to stand upon the same stage as the injection cistern; the contrivance for fixing the springs upon the main triangle legs, and of getting them close enough to take the catch pins, without increasing the length of those pins, will afford an addition of spring; but not being of strength sufficient to receive a dead stroke of the engine without danger of breaking, they are proposed ultimately to bank upon two cross pieces of half a balk, six by twelve, mortised and bed-screwed into the triangle legs, which will also firmly join the legs near the top; the spring frames should be short of banking by an inch, upon these cross pieces, which may be regulated by a small block of wood in the middle, to fill any part of the space between the cross bars of the spring frame and the said cross pieces. Upon the tops of the triangle legs, where they

they are jointed in one, rest the head-stocks, of cast iron, which are each to be bolted down by a couple of perpendicular bolts, as are sufficiently explained in the upright. These iron head-stocks are to contain the brass cods for the gudgeons, and it is to be noted, that the cods are to take quite half the circle of the gudgeons, to prevent the danger of accident by the wheel's jumping out of its place upon a dead stroke upon the bankings. The length of the cylinder in the clear will be six feet six inches, and the length of the stroke, with the springs, down to their ordinary bearings, to be six feet; but I do not expect the working stroke of the engine to be more than five feet eight inches, and to go $14\frac{1}{2}$ strokes per minute. I propose the whole of the great frame, as shewn in the separate sketch thereof, to be of fir; the breadth of the rim of the great wheel outside, where the chains work, to be twelve inches, and the distances of the two chains, middle and middle, to be about $7\frac{1}{4}$ or $7\frac{1}{2}$ inches; the heads of the pins to be outside.

Respecting the water gin, the principal thing that will want explaining is the construction of the reservoir and method of drawing the water upon the wheel. I suppose the column raised by the engine to be thirty-four feet, thirty feet whereof is given to the wheel, three feet head, and a foot allowed for clearance of the wheel at bottom, and the return of the water from the pump's head into the reservoir. To construct the reservoir to hold three feet deep of water would be to burthen it with an unnecessary load, because it never can be drawn off within one foot of the bottom, on account of the waters not having in that case a sufficient velocity upon the wheel; I propose, therefore, that the reservoir be constructed to hold but two feet, or rather two feet two inches water at a full head, and to make good the rest by screwing a trough of ten inches wide, and about five feet long, up against the bottom at the end next the wheel, and in order to let the water down into it, four of the bottom planks to be pierced in the middle of each, with openings of six inches wide, and ten long, equal to the width of the trough below; the last to contain the penstock, sliding in grooves cut in each side of the under troughs, for drawing on, and shutting off the water from the wheel, which is proposed to be regulated by the machine itself at proper times for the meeting and landings of each corf; this will be done by this penstock, as to the reducing or shutting off the water; but as the quantity to be drawn upon the wheel must be exactly regulated by the quantity drawn (in the whole time of bringing up a corf) by the engine, this, I propose to be done by a small regulating shuttle outside the head of the reservoir, which, when once adjusted, is to be screwed fast; it is not to slide in a groove in the trough slides, but to be leathered so as to fill it sideways, and
make

make a water joint; this explanation, together with what will appear by inspection of the draft, will, I believe, be sufficient; the upright and side view of the stage will, I imagine, be sufficient to explain the manner of striking the great wallower out of the geer, and of the application of a convoy to the circumference of one of the great wheels.

In ordinary working, I do not expect that any thing further will be necessary than that, as soon as the corf appears, the bank's man lays hold of it in order to strike it, and as soon as the boy in the cabin upon the stage sees the bank's man have hold of it, or on notice from the bank's man, by means of the tackle, he hauls the great wallower out of the geer; he is prevented from striking it immediately into the opposite wheel by an iron pin that fits two holes through the piece that contains the long mortise, in which the upper part of the upright lever slides, that supports the wallower's gudgeon; when the pin is in one hole, it suffers the upright lever to come into a perpendicular position, but no further; and when in the other hole, it does the same thing when hauled out of the geer the contrary way; before the boy hauls into the geer he takes out the pin, and if after it is in, he puts the pin into the same hole, the lever being then got to the contrary side thereof, it will keep the wallower in its geer; but I expect in common the boy will, when grown expert, rather hold the wallower in its geer, by keeping the tackle tight, than handing the pin for any other purpose than that of preventing the levers passing the perpendicular, which will always be necessary. In this manner I expect the operation will go on, when the people are expert in the use of the different tackle; but, to prevent accidents before they are grown expert, as well as inattention afterwards, I propose two convoys, one upon the great wheel in the cabin, so that if the water wheel happens to have got too much way after the water is taken off, to strike in again upon the other side; he can curb the motion, or stop it if necessary, and if the corf happens to be got too high before the boy strikes out, as indeed is liable often to happen, then the convoy upon the long axis near the barrel being, by means of a cord in the management of the bank's man, he can, on arrival of the corf, clap on his convoy, and prevent the weight of the corf from overhauling the barrel with too much violence; I also have a contrivance of a double ratchet wheel, which, for the sake of farther prevention of accidents, can be applied to the barrel, if thought necessary, or found so, by which the barrel will always be prevented from running back till the bank's man releases the catch; but this, I think, will scarcely be necessary, as I hear they manage at Griff, without any other convoy, except one, applied to the great wheel. The whole is calculated to draw a corf complete in two minutes at Long Benton.

The wallower gudgeon is to reach through the upright lever and end, in a square of about two inches, to which is to be applied the work for governing the shuttle; this is to be a wrought gudgeon, steeled and turned.

As I found, on adjusting my work together, that it would require a very high pair of shears, to draw the bucket out of the pump head, (without unjointing the rod), which would give the whole a top-heavy and cumbrous appearance, I concluded that the easiest way would be to introduce a bucket-door piece, so that, by occasionally hooking a tackle block upon the engine's wheel, to one side or the other, either the piston might be drawn, or the bucket raised to the bucket door, without any additional parts for that purpose. I would advise that the joint of the bucket shank, with the spear, be made with a couple of bolts and nuts, rather than an off-take joint that fixes with a collar, because the nuts can be more easily undone than a hammer used in so confined a place.

I am, dear sir,

Your most obliged servant,

J. SMEATON.

I forgot to say in proper place that the reason why the real head of water would be three feet two inches, when only three feet are allowed, is, that the bottom of the trough would lie two inches below the bottom of the wheel.

LIST of mills executed by Mr. SMEATON, from a paper in his own handwriting.

Vine Elms china mill, wind.
 Bashing wood mill, wind.
 Halton flour mill, water.
 Wakefield ditto, water.
 ——— oil and wood mill, wind.
 Heath engine, water.
 Ridge wood mill, water.
 Honeycomb groat mill, water.
 Brittain furnace, water.
 Carron, ditto, No. 1, water.
 ——— ditto, No. 2, water.
 ——— boring mills, water.
 ——— clay mill, water.
 Waltham Abbey powder mill, water.
 Hounslow Heath ditto, water.
 Buffey mill, flour mill, water.
 Dalry mills, flour mill, water.
 Worcester Park powder mill, water.
 Thornton paper mill, water.
 Bocking fulling mill, water.
 Kilnhurst forge, water.
 ——— flitting mill, water.
 Horsley wire mill, water.
 ——— tilt mill, water.
 Knouchbridge flour mill, water.
 Stratford ditto, water.
 Colchester fulling mill, water.
 Holling's mill, ditto, water.
 Kefwick grift mill, water.
 Hounslow Heath copper mill, water.
 Stratford engine, water.
 London Bridge engine, water.
 Alston grift mill, water.

Woodhall grist mill, water.
 Whittle ditto, water.
 Throchley ditto, water.
 Scremerston ditto, water.
 Wanasworth flour mill, water.
 Carlhalton oil mill, water.
 Hull ditto, water.
 Cardington flour mill, water.
 Leeds pottery mill, wind.
 Deptford flock mill, water.
 ----- engine, water.
 Welbeck engine, water.
 Thoresby ditto, water.
 Wanloch Head slide engine, water.

END OF VOL. II.

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Smeaton, John

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